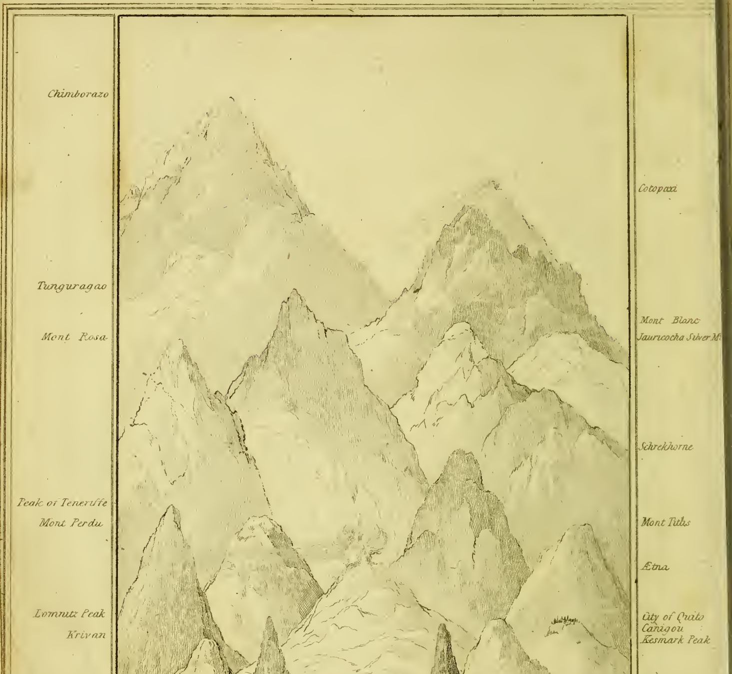
John Burford

Comparative Heights of Mountains. see p. 97.



W. Phillips, del.

Scale 4000 feet to an inch.

OUTLINES

OF

MINERALOGY AND GEOLOGY,

INTENDED FOR THE USE OF THOSE

WHO MAY DESIRE TO BECOME ACQUAINTED WITH

THE

ELEMENTS OF THOSE SCIENCES;

ESPECIALLY OF

YOUNG PERSONS.

ILLUSTRATED BY FOUR PLATES.

Second Edition, revised and corrected.

TO WHICH IS ADDED

AN OUTLINE OF THE GEOLOGY OF ENGLAND AND WALES,

WITH A MAP AND SECTION OF THE STRATA.

BY WILLIAM PHILLIPS,

Member of the Geological Society.

LONDON:

PRINTED AND SOLD BY WILLIAM PHILLIPS,
GEORGE YARD, LOMBARD STREET.

1816.

ADVERTISEMENT TO THE SECOND EDITION.

The favorable reception of the first Edition of this little volume, induced me to attempt the rendering of a second Edition more worthy of attention, by the introduction of some account of the most important Minerals: but I found it impossible to do this without materially altering its character, as a first step to the knowledge of the sciences on which it treats. The attempt however caused the publication of another little volume, entiled '*An Elementary Introduction to the knowledge of Mineralogy, including some account of Mineral Elements and Constituents; explanations of the terms in common use; brief accounts of Minerals, and of the places and circumstances in which they are found.*' This book, will I trust prove a useful companion to the cabinet of the Young Mineralogist.

The principal addition that has been made to this edition is an Outline of the Geology of England and Wales, with a Map, and section of the strata through the southern counties of England; which, concise and incomplete as it is, will be found, it is hoped, of some advantage. This may be had separately; but it is with regret that I do not find it equally possible to accommodate the purchasers of the first edition, in a separate form, with the various corrections and additions interspersed through this.

W. P.

July, 1816.

PREFACE.

The motive for introducing this little volume to public notice, might seem to be wanting if it were not avowed. It is this: There is no elementary work on the subjects it embraces in our language; no book that is calculated, by its simplicity and freedom from theory, and from the shackles inposed upon a learner by the unnecessary use of scientific terms, to invite his attention to the sciences of Mineralogy and Geology.

It is not pretended that the following pages have any claim to originality: all the merit that belongs to them, if indeed any should be allowed, is that of combining in a narrow compass, the outlines of sister sciences which merit a more general attention than is given to them; in an arrangement as simple as the subjects will readily allow, and in language which it is hoped will be intelligible to those who may have no acquaintance with them.

The form in which these outlines are given, that of a division into Lectures, though not absolutely novel, is not common. During the last winter these Lectures were delivered at the neighbouring village of Tottenham, in the order in which they are now printed; but with some deficiences supplied and some errors corrected, that were incidental to hasty compilation. These Lectures were given gratuitously; and the interest they seemed to excite in a numerous audience, principally composed of young persons, and of both sexes, was felt as a flattering compensation.

But the form of Lectures is not adhered to on that account alone. It allows of a familiarity not inconsistent with an elementary treatise, while it affords an opportunity for useful recapitulation, that perhaps would appear objectionable in any other form; and for occasional repetition, which, if the scientific should condescend to peruse it, may seem tiresome, but will, I have no doubt, be advantageous to the learner.

In a work, by far the greater part of which is compilation, it may reasonably be expected that authorities should be quoted. That has not always been done in its pages. I therefore here acknowledge my obligation, in respect to the mineralogical part, to Aikin's Dictionary of Chemistry and Mineralogy; and in the geological part, to the Transactions of the Geological Society, to Cuvier's Theory of the Earth, edited by Professor Jameson, to whose Geognosy I am scarcely less indebted. These works are my principal authorities; many others were occasionally consulted, but were not made use of in a degree that seems to render their enumeration requisite.

If the perusal of this little volume should tend to create in any person the desire for a knowledge of the sciences on which it treats, beyond their mere elements; it must be owned that it is difficult to refer the reader to works in the English language that are adapted to the use of the learner. The only means by which a knowledge of mineralogy can be acquired, is an acquaintance with minerals: and I have no hesitation in recommending those who may feel this laudable anxiety for further information in respect to these interesting pursuits, to the acquirement of it by means of small collections; which may be had of one hundred varieties

and upwards, with an arranged catalogue, of Mawe, 149, in the Strand, at any price between £5 and £100. One of these little collections † would materially assist the progress of the learner; more especially if accompanied by a studious attention to the Manual of Mineralogy, by Arthur Aikin, Secretary to the Geological Society. The introduction to that work, forms a valuable compendium of mineralogical information: and though the learner will meet with many terms and names that will demand explanation, it may be said to be the only work in our language that will be found of advantage to him. The study of geology should follow that of mineralogy. Small collections of rocks may also be obtained.

The Geognosy of Jameson is altogether a scientific work, not well adapted to the learner; inasmuch as a preponderating anxiety for the support of a favorite theory, has caused the introduction of many terms not hitherto adopted by English mineralogists; but much useful and valuable geological information may be gleaned from it.

W. P.

London, 1815.

† These small collections were first introduced to public notice by the recommendation of Dr. Clarke, Professor of Mineralogy at the University of Cambridge.

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LECTURE I.

Preliminary Observations—Objects of Mineralogy and Geology defined—Elementary Substances—Simple and Compound Minerals—Affinity—Crystallization—Structure—Primitive Crystals—Of the Earths—Of the Alkalies.

THE outlines of the sciences of Mineralogy and Geology, of which I am now about to give some idea, are not intended to involve all the nicer inquiries, connected with the subject, that have been instituted by scientific men. Nor do I propose that these outlines shall in any degree be dependant upon, or connected with, the many crude and almost barbarous theories of others, who long amused and even dazzled the world by the splendour of inventions, which tended to retard, rather than to forward, an inquiry into the nature of the globe we inhabit.

The phenomena presented by nature are worthy of our notice; to these your attention will be principally invited.

Of the nature of the earth we comparatively know but little; our investigations are at the best but superficial. We know nothing but of what appears *on*, or *above*, or of what is brought to light by the descent of the miner *beneath*, the general level of its surface; but

the miner rarely descends more than 1500 feet, which is little more than $\frac{1}{30000}$dth part of the diameter of the earth. The globe has often been said to resemble in shape, an orange; in allusion to that resemblance, we may therefore say, that we know nothing but of the outer rind.

The greater number of mineral substances are to the generality of mankind only rude masses, divested of instruction, and equally unintelligent and unintelligible; created only to minister to our necessities. To some, it may be even difficult to imagine how they should become the objects of a distinct science; or that after the miner has brought them to light, the naturalist should find an interest in them previously to their being subjected to the ingenuity of the artist.

The sciences of Mineralogy and Geology are, however, worthy of our attention; they will be found to perform more than they seem to promise. The more we know of them, the more of order, of design, and of contrivance we shall perceive. The power that created the whole is evident in the smallest component part of the most elevated mountain.

Mineralogy has for its object the study of mineral bodies in *particular*; their characters, varieties, forms, and combinations.

Geology embraces the study of the earth in *general*; of its plains, hills and mountains, and of the relative positions of the masses of which they are composed.

Geology comprizes the study of the mass; Mineralogy, of the individual portions, or substances which, by entering into combination, form the mass. A knowledge of mineralogy is therefore essential to the geologist, and for this reason we shall begin with Mineralogy.

It was anciently supposed, when science was under the dominion of fancy and metaphysics, that all natural substances were ultimately resolvable into four simple bodies, viz. *air*, *fire*, *water*, and *earth*, which hence were called the four elements. The ancients however confessed that the precise nature of the two first, air and fire, was not known to them. They supposed most liquids to be modifications of the third element, water; and that the solid parts of the globe were attributable to the last; that is, the element they called earth. Thus, combustible bodies they supposed to contain a combustible earth, and metals a metallic earth.

To modern chemistry we are indebted for a large catalogue of *Mineral elements and constituents.* Besides 9 *earths*, 3 *alkalies*, 27 *metals*, *carbon* and *sulphur* (the two bases of combustible minerals), there are several other substances, essentially differing from the preceding and from each other, which enter into the composition of minerals. It may not be amiss here to enumerate them; but the separate consideration of the nature of each of them, would necessarily lead us further into chemistry than is consistent with our present object. I shall however, as we proceed, notice the nature and properties of some of them in such manner as occasion may require. To the list of 9 *earths*, 3 *alkalies*, 27 *metals*, *carbon* and *sulphur*, above noticed as among mineral elements and constituents, we may add, *oxygen*, *hydrogen*, *nitrogen*, *fluorine*, *chlorine*, *boron*, *phosphorus*, *water*, and certain of the *acids*.

Some of these substances are considered to be *simple* or *elementary* bodies, because the chemist has not been able to decompose them; such are the metals, carbon, oxygen, hydrogen, nitrogen. Others have been partially

decomposed; such are some of the earths, sulphur, and phosphorus; of others the nature is not perfectly understood; as chlorine, fluorine, boron, and some of the acids. Others again are compounds, whose composition is known; such are some of the earths, the alkalies, some of the acids, and water.

From this very brief sketch of the nature of *mineral elements* and *constituents*, it will be seen that there is yet much to learn respecting them; and that the progress of mineralogy is greatly dependent on the advance of chemistry, which is yet far from perfect as a science. It may nevertheless be said that, according to the present state of our knowledge, the foregoing substances contribute to *form all the various constituent masses of the crust of the globe.*

A *simple mineral substance*,* pure Gold for instance, may be described as an *unorganized body*, presenting an assemblage of lesser portions of the same nature, united by the agency or force of a natural law, to which I shall presently advert.

Compound mineral bodies are naturally found in some instances *simply aggregated*, in others *chemically combined.* When simply aggregated, as for instance, when gold occurs in limestone, their separation may be effected *mechanically*, by pounding and washing; but when *chemically combined*, as when silver occurs united with sulphur, we must depend on the labours of the chemist for their separation.

* A simple mineral substance may be chemically described as a substance that has neither been decomposed nor formed by art.

Some of the earths, the alkalies, and some of the metals, are naturally found combined with various *acids*.†

Some of the metals are also found in combination with *oxygen*;* they are then termed *oxides* of those metals; and in that state (to use a familiar illustration) bear the same affinity to those metals, as rust does to iron; rust being the consequence of the absorption by iron, of oxygen from atmospheric air. This chemical combination with oxygen causes metals to assume appearances quite different from the same metals in the pure state; as for instance, the red oxide of copper, is of a ruby red colour, and frequently almost transparent, and the oxide of tin when pure, is nearly colourless and transparent. To shew the liability of mineral bodies to become *compound*,

† Atmospheric, or common air, is composed of two very different kinds of air, or gas, viz. oxygen gas, and azotic, or nitrogen gas, in the proportion of 22 of the former to 78 of the latter.

Oxygen gas, being that part of common air which is essential to animal life, has been also called Vital Air: oxygen gas is composed of oxygen united with caloric, or the matter of heat, whence *oxygen* is termed *the basis of Vital air*.

When a substance is combined with a small proportion of *oxygen*, the compound is called an *oxide:* when with a larger proportion, it is called an *acid*, from the sour taste which most of these compounds possess; and chemists have arranged with the acids some compounds which have not been proved to contain oxygen, because their general resemblance to the acids in other respects is sufficient to warrant the opinion that the similarity holds in this particular also.

When Oxygen is combined with iron, the compound is termed oxide of iron: Oxygen by combining with a certain proportion of carbon or charcoal forms an acid, called the carbonic acid: which, united with lime, forms a compound mineral called carbonate of lime, of which one variety is limestone, and another is chalk.

* See the above note.

it may be noted that the ore called white silver, is composed of four metals, silver, lead, antimony, iron; two earths, alumine and silex; and one combustible, viz. sulphur.

The water which enters more or less into the composition of some mineral substances, is termed *water of crystallization* when these substances possess a *regular structure.*

The law to which an allusion was just now made, as being that to which are subject the elementary substances, of which the masses constituting the globe are composed, is called *Affinity*. This law may be said to involve in it, all those termed attraction, gravitation, magnetism, and electricity. To the law of affinity, mineral bodies owe their existence in separate and similar masses, as well as their regular crystalline forms; and but for this important law of nature, the solid parts of the globe would only have been a chaotic mass, instead of exhibiting, even in the oldest rocks, deposites of distinct substances frequently in regular crystalline forms.

Before we proceed to consider the nature of the Earths, Alkalies, Metals, and the bases of combustibles, either separately, or as entering prominently into combination in certain minerals, I shall invite your attention to that consequence of the law of affinity, which is termed *Crystallization*. It seems necessary here to introduce this part of our inquiry, because in speaking of earthy and metalliferous substances, I shall present to your notice specimens, some of which exhibit those bodies in their natural crystalline forms. This subject, when considered at large, is curious and interesting; its investigation, keeping pace with other rapid advances in science, has

of late been dignified by the adaptation of geometry and algebra to its illustration. In the narrow compass of what I have undertaken, it is impossible to give more than a very limited view of the subject, but I shall endeavour to make its general outline understood, avoiding, on this, as on all other occasions, as much as possible, all technical and scientific terms.

The term *Crystal*, is derived from the Greek Κρυσαλλος (Crustallos), signifying ice, which was so called on account of the ease with which it liquified. The term crystal was afterwards applied to what is now called Rock crystal, by the Roman naturalists, as supposing it, both from its transparency and beautiful symmetrical forms, to be only water indurated by continued frosts in the mountainous regions of the Alps. But finding that certain salts * also took a prismatic form, the term *crystal* assumed a more general meaning, and now includes all the *regular*, *many-sided solids*, whether of earthy or metalliferous substances, presented either by nature or chemistry.

There are comparatively very few substances that are not found naturally crystallized with more or less regularity. The forms assumed by some are very numerous and highly interesting. For instance, the carbonate of lime has been found in about 300, and the oxide of tin in about 180 varieties of form : and as of both these, as well as most other substances, the crystals *may be broken*

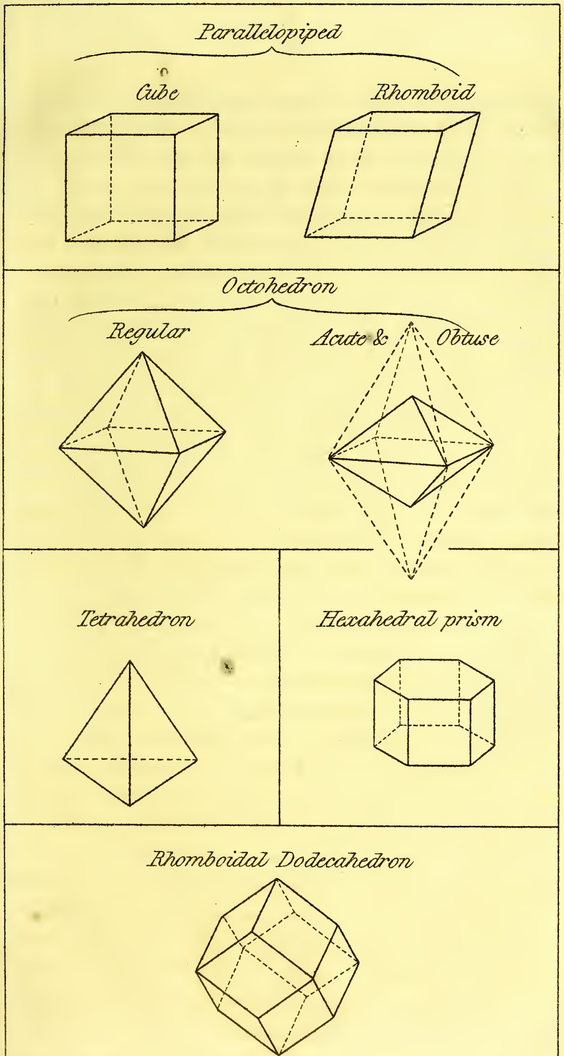
* The term *Salt* has been so variously applied, that it is scarcely possible to give an accurate definition of it. It is now sometimes used to designate all the crystallizable acids, or alkalies, or earths; or combinations of acids with alkalies, earths, or metallic oxides. Hence the division of compound salts, into earthy, alkaline, and metallic.

in particular directions, the true definition of a crystal seems to be this, that it has not only *a regular external figure*, but also *a regular internal structure*. This structure in the crystals of several minerals, is readily exemplified by mechanical means, producing fractures, or cleavages of perfect regularity. Some, even small crystals, have been found exhibiting upwards of 150 little planes; but as most crystals can be broken in particular directions, we are enabled to trace these complicated forms through their many intermediate varieties, into *one simple form*, which therefore is termed the *primitive crystal* of that substance. The crystals of many minerals assume the same figures, and therefore are readily traced to the *same* primitive form. If we take into consideration the whole range of substances found in a crystallized state, the *primitive forms* of their crystals, numerous, varied, and complicated as many of them are, may be said to be comprehended in the five following solids; see plate 2.

The Parallelopiped,
Octohedron,
Tetrahedron,
Hexahedral prism,
Rhomboidal dodecahedron.

The *Parallelopiped* may be said to comprehend *every solid contained under six parallelograms:* that is, under six planes, whose bounding lines two and two are parallel with each other, and whose opposite sides are equal and parallel. Of these solids, the cube and the rhomboid are selected as the most common: there are also others more or less allied to these. The cube is a body of perfect proportion; all its sides are equal—all its planes are square. The primitive forms of some sub-

Plate 2. *Primitive Crystals*



stances are much flatter than the cube; of others, they are much higher: these are then termed *square prisms*. The rhomboid differs from the cube essentially; none of its planes are square, but they resemble each other; two of the opposed angles of each plane are more obtuse, the other two are more acute, than those of the planes of the cube. Of rhomboids there are several varieties; that is, the angles of their planes are more or less acute and obtuse: these rhomboids therefore differ in a greater or less degree from the proportions of the cube. There are some other varieties of the parallelopiped which it is not essential to our present object to explain.

Of the *Octohedron* also there are several varieties: three of the most obvious are selected. The *regular* octohedron, is so called, because it is a solid contained under eight planes, each of which is a triangle equal and similar to each of the others; and which, having all its three sides of the same length, is therefore termed an *equilateral triangle*. A line drawn from its summit to its lowest extremity or angle, is precisely of the same length as a line from any other of its angles to its opposed angle. As the primitive crystal of some substances, is found an octohedron, much flatter than the regular, and therefore called an *obtuse* octohedron: two of the three lines, bounding each of its eight triangles, are shorter than the third. A line drawn from the summit to its lower extremity or angle is shorter than a line from any of its other angles to its opposed angle. An octohedron is found to be the primitive crystal of some substances which is much longer than the regular octohedron, and is called *acute*, because its upper and lower angles are more sharp or acute than the other four angles. Two of the three lines bounding each of its eight tri-

angles, are longer than the third; and a line drawn from the upper to the lower extremity or angle, is much longer than one drawn from either of its other angles, to the opposed angle.

Of the octohedron there are some other varieties, of which it is not now requisite to enter into an explanation.

The *Tetrahedron* is a solid comprehended within four planes, each of which is a triangle equal and similar to the rest, having each of its three sides of the same length. It is the simplest of all the primitive forms.

The *Hexahedral prism* is a solid comprehended within eight planes, which are not all similar. Its upper and lower planes, called the *terminal* planes, are alike, being six-sided or hexagonal: each of the six sides being of the same length. The other six planes, which are called the *lateral* planes, are alike in regard to each other, and in the figure in plate 2, are each perfectly square. This is not always the case in primitive crystals; in some, the lateral planes are much longer, in others shorter; in either of which cases the lateral planes would not be square, but oblong. Hexahedral prisms, as primitive crystals, are therefore of various lengths.

The *Rhomboidal dodecahedron* is a solid comprehended within twelve planes, all of which are perfectly alike in form; each plane being a rhomb, of which the four bounding lines are all equal in length, and are parallel two and two, forming two acute and two obtuse angles on each plane.

But, certain substances are naturally found to assume two of those, which are termed *primitive forms*. Amongst these is the fluate of lime; it therefore becomes a question, which of the two is the *true* primitive

form of that substance. This question is decided by the *internal structure* of the crystal. If we take a crystal of it in the form of the *cube*, we shall find that all its corners, termed the solid angles, may be regularly broken off, so as to produce in lieu of each of them, a regular triangular plane, and that, by pursuing this fracture, we shall finally arrive at a form which in fact is the *regular octohedron*, which therefore is proved to be the *primitive* form of the fluate of lime; of which, it is also proved, that the *cube* is only a *secondary* crystal, the result of an aggregation of laminæ on the several planes of the octohedron; in other words, by the addition of laminæ, or regular layers, parallel with the planes that may be obtained by mechanical cleavage.

If however we take a similar crystal, that is, a cube, of common salt, we shall find that it is not the result of the same law of crystallization; that is, we shall find that it cannot be fractured in the same way, the corners or angles cannot be taken off; and as it can be fractured only in the *direction of, or parallel with the six faces* of the *cube*, that solid is therefore esteemed to be the primitive form of common or rock salt. But by adding regular layers parallel with the planes obtainable by mechanical cleavage, that is, on the six planes of the cube of rock salt, we should never obtain an octohedron; accordingly rock salt is never found crystallized in the form of the octohedron.

The carbonate of lime is always readily broken into *Rhomboids*, and no other form.

The crystals of the fluate and the carbonate of lime, and of common salt, are quoted as remarkable instances of the ease with which their natural structure affords mechanical cleavage; but, all mineral substances are not

fractured with the same ease. The topaz can only be readily cleaved in one direction: the crystals of some minerals, although they may be cleaved in several directions, can only be readily fractured in one or two: and the crystals of several substances, although they sometimes present indications of their real structure, have never yet been regularly fractured. This diversity in the structure of crystallized bodies has not been satisfactorily explained; we only know the fact.

It has already been said that the mineralogist depends on internal structure, for a knowledge of primitive forms; but where the knowledge of this structure cannot be attained by mechanical means, recourse must be had to other means: analogy seems the only resource. In other words, a comparison of the external forms of such crystals as do not admit of a mechanical cleavage, with the external forms of the crystals that do admit of it; but this is sometimes the source of error.

It may readily be supposed that the regular internal structure so observable in the crystals of many substances, would necessarily produce a regular external form. This actually exists in a degree scarcely credible by those who have not examined the subject, both in those crystals of which the internal structure is known, as well as in those of which it is not.

Much attention has lately been given to ascertain precisely, the angles at which the various and even numerous planes of crystals meet each other. For this purpose an instrument has been invented, called the *goniometer*, meaning the measurer of angles; but we may conclude that its use scarcely admits of perfect accuracy; and for this reason; the few most conversant in its use, have differed in the results obtained from the same substances.

Another instrument has lately been invented by Dr. Wollaston, called the *reflecting goniometer*, because its use depends on the reflections to be observed upon the natural polish on the planes of crystals. This instrument has already done service to science in detecting some fallacies, arising from a reliance on the former instrument.

When once the angles of the primitive crystal of any substance are accurately ascertained, the angle at which any two of its numerous planes meet, is calculated with wonderful precision by the assistance of geometry.

The angles formed by the meeting of any two planes of each of the five regular solids, the cube, the regular octohedron, the tetrahedron, the hexahedral prism, and the rhomboidal dodecahedron, already enumerated among primitive crystals, are known, because they all are *regular geometrical solids*. But it has already been shewn, that there exist as primitive crystals, *varieties of the parallelopiped and of the octohedron*, which differ from each other both in shape and measurement. As instances; the primitive crystal of quartz, is a rhomboid very different to that of carbonate of lime, and much more nearly approaches the cube. The primitive crystals of the oxyd of tin and of zircon, are octohedrons, differing from each other, but are much more flat than the regular octohedron; while the octohedron which is the primitive crystal of sulphur, is much longer and more acute. The primitive crystal of the cyanite is a four-sided and oblique prism, with rhombic terminations, while that of the sulphate of barytes is a four-sided rhomboidal prism also with rhombic terminations. The difficulty therefore is, to obtain the precise admeasurements of those primitive crystals, which are *not re-*

gular geometrical solids. It is probable that the reflecting goniometer of Dr. Wollaston will discover, that the principal part of the calculations hitherto made in regard to the angles of such primitive crystals, and of the numerous facets to be observed on them, (which not belonging to the primitive crystals, are therefore termed *secondary planes)*, are incorrect; and for this reason; this goniometer will assist in measuring the angles of crystals as small as the head of the smallest pin, if their planes be perfectly brilliant; and it is ascertained that minute crystals are always more perfectly formed than large ones. Now the calculations already alluded to are grounded upon measurements taken by the common goniometer upon large crystals, the planes of which rarely are perfectly formed and smooth: even such as have brilliant planes, and seem therefore adapted to the use of the reflecting goniometer, seldom afford similar results.

I shall now offer to your notice some observations on those substances which are termed *Earths*; they are nine in number.

1. *Silex*	6. *Barytes*
2. *Alumine*	7. *Strontian*
3. *Zircon*	8. *Lime*
4. *Glucine*	9. *Magnesia*
5. *Yttria*	

All these *earths* agree, when free of foreign admixtures, in this one character, they are all *snow-white.*

Although these substances by common consent retain the name of Earths, it seems essential, in speaking of them as mineral constituents, to say that chemistry, which, during the last twenty years has made amazing

progress, has by the late brilliant discoveries of Sir Humphrey Davy, completely turned the tables on the ancients. They supposed that every metal had an *earthy basis*, whereas his experiments tend to shew, that several of the earths have *metallic bases;* that, in fact the whole number of them are *not simple* or *elementary substances*, but *compounds*, consisting of oxygen united with certain bases; and, if it be admitted that these bases are metals, the Earths, to use the same familiar illustration as before, have the same affinity to their respective metallic bases, as rust has to iron; *they are metallic oxides.* The earths whose bases are best known are those called barytes, strontian, and lime; they are considered by Sir H. Davy to be metals. Strictly therefore we ought to diminish the number of earths, by the three in question, and to increase the number of metals; but as discoveries however brilliant and however well established, are rarely admitted with instantaneous consent, these *metallic oxides* are still suffered to hold their places as *earths.*

I now proceed to give some account of each earth separately, and shall offer to your inspection some specimens of substances in which they prominently enter into combination.

The first on the list is Silex. This is one of those earths which the discoveries of Sir H. Davy have not decidedly shewn to have a metallic basis; its base he has called *Silicium*, which he is now of opinion is not a metal, but that it is a substance of a peculiar nature. Silex in its pure state is not three times as heavy as water, and has neither taste nor smell. It has never been found combined with an acid.

As common flints are almost wholly composed of *siliceous earth*, it has from that circumstance received the name of *Silex*, which in Latin signifies *Flint;* but this earth is found in greater purity in opal, and in quartz or rock crystal.* Silex is probably the earth which most abundantly enters into the composition of the globe. It is proved by analysis to enter, in variable proportion, into the composition of about two thirds of all the earthly minerals whose composition is known; and as it is the chief ingredient of the oldest and most plentiful of the primitive rocks, and is found in rocks of almost every age and formation, it is esteemed to be the most abundant substance in nature.

Silex enters largely as a component part of glass, for which purpose the pure sand from some parts of the coast of Norfolk, and Alum Bay in the Isle of Wight, are preferred.

Alumine has been so called from its forming the basis of common alum. When pure, it has neither taste nor smell, and is twice as heavy as water. Though one of the most extensively diffused substances, it is no where found pure; and though a constituent part of the purest clays, it rarely forms more than one-fourth or one-third part of them; it is however found nearly pure in the oriental ruby and the saphire, and in corundum, which are the next in hardness to the diamond.† Alu-

* *Quartz* is composed of silex, with 2 or 3 parts in the 100 of water. *Opal*, of 90 parts of silex and 10 of water. *Flint*, of 97 parts of silex, 1 of alumine and oxide of iron, and 2 of water.

† By analysis, the *Saphire* yields about 98 parts of alumine, 1 of oxide of iron, and a small portion of lime; the *Oriental Ruby*, 90 parts of alumine, 7 silex, and some oxide of iron: *Corundum*, about 89 parts of alumine, 5 of silex, and nearly 2 of oxide of iron.

mine forms a large proportion of that valuable mineral called fullers' earth, which has that smell when breathed on, peculiar to clayey substances, and which forms a mineralogical test of the presence of alumine. It occurs combined with the *sulphuric acid*,* in alum, and with the *fluoric acid*† in a few rare minerals. Alumine consists of oxygen united with a base, *Alumium*, the nature of which has not been completely ascertained.

It is an ingredient, in large proportion, of some of the most abundant rocks, primitive, secondary, and alluvial, and is found in all soils ; it is the most abundant of all the earths except silex.

In useful purposes, alumine enters largely into the composition of bricks, pottery and porcelain ; it is infusible.

Zircon when pure, is rough to the touch, insipid, and insoluble in water; it is found combined with other substances in a few rare minerals ; in the hyacinth, from a brook called Expailly, in Auvergne in France ; and in the jargoon from Ceylon.‡ Hitherto zircon has not been put to any useful purpose ; it is about four times as heavy as water. Zircon is composed of oxygen united with a base, *Zirconium*, the nature of which is not known.

The earth called Glucine obtained that name from the Greek γλυκος, signifying *sweet*, on account of the

* The *Sulphuric acid* consists of sulphur and oxygen. *Alum* consists of the sulphuric acid, alumine, potash, and water.

† The *Fluoric acid* consists of hydrogen, and a substance which is denominated *Fluorine*, but which has not been seen in a separate state.

‡ The *Hyacinth* is composed of 70 parts of zircon, 25 of silex, and a trace of oxide of iron. *Jargoon* of 66 parts of zircon, 31 of silex, and 2 of oxide of iron.

sweet taste by which its salts are distinguished. When pure, glucine is a white powder, soft, and somewhat unctuous to the touch, and is nearly three times the weight of water.

The nature of its base, *Glucinum*, which by a natural combination with oxygen constitutes glucine, is unknown.

In the natural state, glucine has hitherto only been found in small proportion in the beryl, the emerald,* and the gadolinite ; but neither the pure earth nor any of its salts have hitherto been applied to any use.

Yttria, in many of its properties and appearances in its pure state, bears considerable affinity to glucine ; it has the same saccharine taste, but is easily distinguished from it, inasmuch as it is nearly five times heavier than water, and by some properties discoverable only by the chemist.

It is an extremely rare earth. In the natural state, yttria occurs as a component part of the mineral substance, called gadolinite,† which is brought only from Sweden, and which was so called on account of its having been first analyzed by the Swedish professor Gadolin, who named the earth yttria, because the mineral in which it was discovered, was brought from Ytterby in Sweden. It occurs only entering into the composition of another scarce mineral, Yttrotantalite, and is therefore a very rare earth.

* The *Emerald* is composed of about 64 parts of silex, 16 of alumine, 13 of glucine, 1 of lime, and nearly 4 of oxide of chrome.

† The *Gadolinite* is composed of about 56 parts of yttria, with a trace of manganese, 22 of silex, 5 of glucine, 17 of oxide of iron, a small portion of alumine, and some water.

Barytes has never been found pure in the natural state, but always combined, either with the *sulphuric acid* forming sulphate of barytes or heavy-spar; or with the *carbonic acid** forming carbonate of barytes, or witherite.† Barytes and all its salts, except one, are violent and certain poisons, destroying animals by inflaming the intestines, and are often used for the destruction of vermin. Barytes is not a very abundant earth. It is one of those that have lately been decomposed by Sir H. Davy; who discovered that it consists of *oxygen* united with a base, which he denominates *Barium*, and which he considers to be a metal.

Strontian has never been found in a pure state. It was first brought, combined with the *carbonic acid*, from a place in Argyleshire, called Strontian, whence the mineral obtained its familiar name of strontianite. Strontian combined with the *sulphuric acid* is found near Bristol; thus combined, the mineral has obtained the name of cœlestine,‡ from its delicate tint of a light blue colour.

Strontian consists of oxygen, united with a base, *Strontium*, which is believed more nearly to approach the nature of the metals, than the bases of some of the preceding earths. It may be considered as a rare earth.

* The *carbonic acid* consists of oxygen and carbon.

† The *Witherite* is composed of 78 parts of barytes and 22 of carbonic acid. *Heavy Spar* is composed of 67 parts of barytes, and 33 of sulphuric acid.

‡ The *Strontianite* is composed of about 69 parts of strontian, 30 of carbonic acid and a little water. *Cœlestine*, of 54 parts of strontian, and 46 of sulphuric acid.

Either when pure or combined with the acids above mentioned, strontian has not hitherto been applied to any use. At present therefore these combinations merely serve to form a part of a mineralogical collection.

Lime has never yet been found in a pure state, but when so prepared by the chemist, is moderately hard, and of a hot acrid taste. It has been proved by Sir H. Davy to consist of oxygen united with a basis, considerably resembling some of the metals, which he calls *Calcium* : lime is therefore considered to be a metallic oxide. It naturally occurs in combination with the *carbonic*, *sulphuric*, *boracic*,* *arsenic*,† *fluoric*, *nitric*,‡ *and phosphoric acids*.||

Lime combined with the *carbonic acid* forms a mineral substance, thence termed *carbonate of lime*,§ which is very abundant. Carbonate of lime, when crystallized, is commonly called *calcareous spar*. It assumes a vast number of beautiful and regular forms, all originating in a rhomboid, which may always be obtained by fracturing the crystals, and which therefore is denominated the primitive form of its crystals.

* The *Boracic acid* consists of oxygen and Boron. The nature of Boron is not understood ; it is a combustible substance, differing from every other known species of matter.

† The *Arsenic acid* consists of oxygen united with arsenic, one of the metals.

‡ The *Nitric acid* consists of nitrogen and oxygen.

|| The *phosphoric acid* consists of phosphorus, united with oxygen. The nature of phosphorus is not precisely understood ; but it is supposed that hydrogen is one of its component elements.

§ *Calcareous Spar* or carbonate of lime, is composed of 57 parts of lime, and 43 of carbonic acid.

Those minerals commonly called limestones, and chalk, and marble, are also carbonates of lime. The uses to which lime is applied, (when the carbonic acid with which it is combined, as forming chalk and limestone, is driven off by heat) are well known. The rocks on each side the Avon near Bristol, are of a peculiar kind of limestone, which has obtained the name of swine-stone, from its yielding when rubbed a fetid smell. This smell was heretofore attributed to the presence of bitumen, but is now believed to be owing to sulphuretted hydrogen. Carbonate of lime is so abundant, that it is estimated to form one-eighth part of the whole crust of the globe.

Lime in combination with the *sulphuric acid*, is called *sulphate of lime*, or familiarly *gypsum*.* Of this mineral the uses are very extensive. When compact, it is called *alabaster*, and is employed by the architect for columns and other ornaments, being more easily worked than marble; it is also turned by the lathe into cups, basins, vases, and other similar articles. When sulphate of lime or gypsum, is subjected to a certain heat, it loses what is termed its water of crystallization, and is converted into a fine powder called *plaster of paris;* the uses of which, when beaten up with water into a paste, for taking casts of gems and statues, are well known.

Lime combined with the *arsenic acid*, forms a mineral called Pharmacolite;† the only species: with the

* *Gypsum* is composed of about 32 parts of lime, 46 of sulphuric acid, and 21 of water.

† The *Pharmacolite* is composed of about 46 parts of arsenic acid, 23 of lime, 6 of silex, 22 of water, and a small portion of oxide of cobalt.

boracic acid, a mineral is formed called the datholite.*

Lime combined with the *fluoric acid*, is called *fluate of lime*. This mineral is commonly known by the name of fluor spar;† in Derbyshire, as blue john. The elegant vases and chimney ornaments turned by the lathe out of blocks of this substance, are known to almost every one; the brown colour generally observable in these vases is obtained by exposure to heat. Fluate of lime is extensively used in smelting the ores of copper.

The mineralogist values the fluate of lime for its abundant and beautiful variety of crystals both in form and colour; all the forms it assumes may be traced to the regular octohedron, which therefore is termed the primitive form of its crystals. The octohedron may be obtained from each of them, however unlike to it, by breaking it in certain directions.

A variety of fluate of lime, called chlorophane, found in Siberia and Cornwall, on being exposed to the heat of a live coal gives out a beautiful green light.

Lime in combination with the *phosphoric acid*, forms a mineral which occurs in small crystals, called apatite,‡ or phosphate of lime.

In combination with the *nitric acid*, it forms a mineral called nitrate of lime, which occurs in silky efflorescences on old walls, and sometimes in mineral waters.

* The *Datholite* is composed of about 36 parts of lime, 36 of silex, 24 of boracic acid, and 4 of water.

† *Fluor Spar*, or the fluate of lime, yields by analysis about 68 parts of lime and 32 of fluoric acid.

‡ *Apatite* yields 55 of lime and 45 phosphoric acid.

MAGNESIA is a light earth of a perfect whitenesss, and is absolutely insipid ; the slightly acrid taste occasionally to be found in the magnesia used in medicine, arises from a proportion of lime. Naturally, magnesia occurs combined with the *boracic acid*, in the borate of magnesia, or boracite.*

In the rare mineral by some called native magnesia, analysis has proved it to be combined with the *sulphuric* and *carbonic acids*.

Magnesia consists of oxygen united with a base, *magnesium*; the nature of which is imperfectly known.

Magnesia is not an abundant substance; it enters into the composition of about 30 minerals, but, in most of them, it is not the prevailing ingredient. It forms a small proportion of that substance called the *soap-stone*, which owes its greasy or soapy feel to magnesia. The soap-stone is largely employed in the manufacture of porcelain.

These nine earths enter, in very different proportions into the composition of the globe.

It is considered that silex is the most abundant of all. It forms the greatest ingredient of the oldest rocks, is largely found in others, and in clays and soils; in these alumine is the next in abundance; to it succeeds lime, which is less common in primitive rocks, though

* The *Boracite* is composed of about 17 parts of magnesia and 83 of the boracic acid. The *Spinelle Ruby*, about 85 parts o alumine, 9 of magnesia, 6 of chromic acid. *Asbestus*, 59 parts o silex, 25 of magnesia, 9 of lime, 3 of alumine. The *Soap-stone*, of about 59 parts of silex, 30 of magnesia, 2 of oxide of iron, and 6 of water.

very plentiful in the transition and flœtz, or secondary rocks.

Magnesia and barytes occur in comparatively very small quantities. The first enters but little into the composition of rocks and soils; the latter rarely.

Strontian, zircon, glucine, and yttria, are very sparingly found; the first is the most common of the four; the others are only found in part the components of a few mineral substances, some of which are occasionally enclosed in rocks; but rarely does any one of these four earths enter into the composition of rocks or of soils.

Barytes, magnesia, strontian and lime, are never found pure; but mostly combined with acids. These four earths agree so nearly with the alkalies in some of their chemical properties, that some chemists have given them a place among the alkalies, others have termed them alkaline earths.

We now proceed to those mineral substances termed Alkalies, which enter into the composition of several minerals.

The term *Alkali* is Arabic, and is expressive of the acrid saline residue left in the ashes of the plant called *Kali*, after its combustion in the open air; and not being volatilized by a moderate heat, was termed *Fixed Alkali.* But there is another Alkali, differing essentially in respect of composition from the fixed Alkalies, but agreeing with them in certain chemical properties, which, being volatilizable at a moderate heat, is therefore termed *Volatile Alkali.*

Fixed Alkalies are usually denominated of two kinds. The *Vegetable* or Potash, and the *Mineral* or Soda. *Potash* is procured from the ashes of vegetables

in general *not* growing contiguous to the sea. *Soda* is the basis of common salt, and is therefore found in immense quantities ; it is also the principal saline residue procured by the combustion of plants growing *on* the sea shore.

The taste of the fixed alkalies, is acrid, burning and nauseous, they are without smell, they have peculiar chemical properties which it is not essential to our present object to notice.

POTASH occurs in the natural state in felspar, and in mica, and in about twelve other substances ; therefore the term vegetable as applied to potash is not absolutely correct.

SODA is found naturally combined with the *carbonic acid*, forming carbonate of soda, the *sulphuric acid* forming sulphate of soda, the *boracic acid*, forming borate of soda, and with the *muriatic acid*,* forming muriate of soda or common salt.† It likewise enters into the composition of about twelve earthy minerals.

The mineral called fettstein, and several other minerals, yields by analysis both potash and soda.‡

Both potash and soda are largely employed in the making of glass and soaps. When pure, they are not easily distinguished from each other, but potash is the heaviest. Until lately, both potash and soda were

* The muriatic acid consists of Chlorine and hydrogen. The nature of Chlorine is not understood. It has never been decomposed.

† The water of the ocean contains from one-twenty-fifth to one-thirty-fifth of its weight of muriate of soda, or common salt, which is composed of 53 parts of soda, 47 of the muriatic acid.

‡ The *Fettstein*, 44 silex, 34 alumine, 4 oxide of iron, a small portion of lime, and 16 parts of soda and potash.

believed to be simple substances, but by the experiments conducted by Sir H. Davy, with the astonishing powers of electro-chemical agency, they have both, as well as the earths, been actually decomposed. The mode by which this was effected is highly ingenious and interesting; the detail belongs to the chemist. The result however was, that *potash* was found to be a combination of *oxygen* with a substance resembling quicksilver in appearance, and which by the discoverer has been called *Potassium*,* as being the basis of potash. The result was exactly similar in regard to *soda*, the basis of which he called *Sodium*.† Both *Sodium* and *Potassium*, are considered to be metals; they are malleable, and in this respect agree in character with iron, copper, and some other metals; but they are lighter than water. Both potash and soda are metallic oxides. Nevertheless potash and soda still hold their rank as fixed alkalies.

It is by no means improbable that future researches in chemistry will also discover the nature of the bases of all the substances now ranked as earths, some of which are yet unknown, and that by common consent, the substances called the earths, and those termed fixed alkalies will be swept away, and their bases added to the catalogue of metals.

Volatile Alkali, or Ammonia, when pure, subsists only in a gaseous form. It consists of hydrogen‡ and

* *Potash* consists of about 17 per cent of oxygen, combined with 80 per cent of potassium.

† *Soda* consists of about 22½ of oxygen and 77½ of sodium.

‡ Hydrogen is considered to be an elementary body. The most simple form in which it has been obtained is that of a gas, in which it is in union with caloric, or the matter of heat.

nitrogen;* and perhaps also a small proportion of oxygen. Volatile alkali is found only in combination with the *sulphuric* and *muriatic* acids, forming sulphate and muriate of ammonia. The former is found in certain lakes in Tuscany. Muriate of ammonia, also called sal ammoniac, is chiefly found in the crevices of the lavas of Etna and Vesuvius, and in coal.

The discoveries just noticed have been effected by the aid of galvanism superadded to chemistry. Galvanism or electricity therefore (for a doubt of their identity scarcely exists) holds a high and important station in science. With such aid, chemical experiment, conducted by such men as Sir H. Davy, may work a complete reformation in science: it is impossible even to conjecture where discovery will stop.

* The nature of nitrogen is not precisely known. It is suspected not to be a simple or elementary body. In combination with caloric, nitrogen is one of the constituents of atmospherical air.

LECTURE II.

Of the Metals—Of Combustibles.

On a former evening it was said that mineral substances are considered to be of four kinds, Earthy, Alkaline, Metallic, and Combustible.

That they are naturally found either simple or compound: the simple consisting of one substance alone; the compound of two or more; and that these are either mechanically or chemically combined.

That some of the earths and metals are found combined with various acids; and some of the metals with oxygen, or the basis of vital air.

It was also said that by the aid of chemistry, nine earths had been discovered, and three alkalies; but that Sir Humphrey Davy, by the assistance of electro-chemical agency, had lately proved that some of the earths, as well as both the fixed alkalies, are compounds, having bases which in some of their properties are nearly allied to the metals; and that they consist of oxygen in combination with those bases.

Having also in the former evening considered some of the properties and uses of the earths and alkalies, we shall now proceed to notice the metallic bodies, and afterwards those substances which are called combustibles.

The only metals known to the ancients were gold, silver, copper, iron, tin, lead and mercury; but discoveries have from time to time increased the catalogue, until it has been swelled to the number of twenty-seven, independently of those which have very lately been discovered as the bases of some of the earths and the two fixed alkalies.

Of these metals the first eleven only have the important property of malleability, or of being sufficiently tenacious to bear the extension of their body by beating with the hammer; the others have by some been therefore termed brittle metals.

Malleable Metals.	*Brittle Metals.*	
Platina,	*Arsenic,*	*Molybdena,*
Gold,	*Antimony,*	*Tungsten,*
Silver,	*Bismuth,*	*Chrome,*
Mercury,	*Cobalt,*	*Osmium,*
Lead,	*Manganese,*	*Iridium,*
Copper,	*Tellurium,*	*Rhodium,*
Tin,	*Titanium,*	*Uranium,*
Iron,	*Tantalium,*	*Cerium.*
Zinc,		
Palladium,		
Nickel.		

A lustre is peculiar to the metals, which therefore is called the metallic lustre: another remarkable property is their want of transparency when in the mass; but as leaf gold held between the eye and a luminous body transmits a green light, and silver a white light, it seems probable that other metals, if attenuated in the same degree, would also be translucent.

In weight the foregoing metals far exceed the earths;

the heaviest of the earths is only about five times heavier than water, but the lightest of the metals is more than six times heavier than water. Beaten gold is nineteen times heavier than water, and beaten platina, the heaviest of all, is twenty-three times heavier than water.

The characters of fusibility and extensibility in metals is of vast importance to man; for without these characters neither could they be freed from the earths and other impurities with which they are naturally found, nor wrought into vessels for his use.

Metals are believed to be *simple substances: not one of them has hitherto been decomposed.*

The only metals that as yet have been found in the metallic or *native* state, are platina, gold, silver, quicksilver, copper, antimony, arsenic, tellurium, bismuth and iron. But the greater part of these are rarely found quite pure, but mostly have small proportions of other metals intermixed.

In order to illustrate the very brief view I am about to take of the several metals, I shall offer to your inspection specimens of some of them as they are naturally found either in their simple state, (if so found) or as forming those compounds which are denominated *metalliferous ores.*

An *ore* is a compound of two or more metals, or of a *metal in combination with oxygen;* (whence such a combination has obtained the name of a *metallic oxide;)* or a metal combined with an *acid*, or with a *combustible.* Many ores are of so compound a nature as to consist of two or three metals united with oxygen, sulphur, one or more of the earths, and with water.

I now proceed to invite your attention to the metals individually; beginning with those which possess the qualities of fusibility, ductility and malleability, so important to man.

Platina is about twenty-three times heavier than water; hitherto it has only been found in Peru, Brazil, and in the island of St. Domingo. In Peru, it is found in little flattened grains, rarely exceeding the size of a pea, accompanied by gold and the ores of titanium and iron; yet it is said that Humboldt presented the King of Prussia with a mass larger than a pigeon's egg. But the grains of *crude* platina are not pure; analysis has proved them to consist of platina alloyed by seven other metals, osmium, iridium, rhodium, palladium, iron, copper and lead, which will hereafter be noticed. The platina of Brazil is alloyed by gold and palladium.

Crude platina is very difficult of fusion. Pure platina in thin plates is very ductile and flexible. Of late it has been formed into mirrors for reflecting telescopes, spoons, crucibles, and some vessels of considerable dimension for the use of the chemist in particular processes. So ductile is platina, that Dr. Wollaston has lately succeeded in drawing it into a wire $\frac{1}{18750}$ part of an inch in diameter.

Gold, when pure and beaten, is about nineteen times heavier than water; it is very soft, and perfectly ductile and flexible. So great is the tenacity of gold, that a piece one-tenth of an inch in diameter, will hold five hundred pounds without breaking; and it is computed that a single grain of gold will cover the space of fifty-six square inches, when beaten out to its greatest extent.

Gold is mostly found in the metallic form, whence,

by mineralogists it is said to occur in the native or pure state; but it is generally alloyed by small portions of other metals, as silver, copper, &c. It occurs in mineral veins in primitive mountains but not of the oldest formation: it is thus found in Brazil, Peru, Mexico, Hungary and Transylvania.

Sometimes gold is crystallized in small cubes or regular octohedrons, and as these crystals cannot be broken in any particular direction, either of those solids may be said to be the primitive crystal of gold. In veins it is generally accompanied by quartz, felspar, the ores of silver, lead, and of some other metals.

Helms says, that when a projecting part of one of the highest mountains in Paraguay fell down, about thirty years ago, pieces of gold, weighing from two to fifty pounds each, were found in it; and that in the Vice-royalty of La Plata alone, there are thirty gold mines.

A great quantity of gold is obtained in grains and rounded masses in soils, evidently the ruin of rocks which contained it in its natural situation. In this state it has been found in Wicklow in Ireland, and in Cornwall, in small quantities. A few years ago a single specimen of gold, equal in weight to upwards of ten guineas, was found among tin in a stream work in Cornwall. On the coast of California there is a plain of fourteen leagues in extent, about fourteen inches beneath the surface of which, large lumps of gold are irregularly interspersed.

But a still greater quantity of gold has been obtained in the form of a fine sand, from the Peruvian, Mexican and Brazilian rivers, and from some of the African. In Europe, the Danube, the Rhine, and the Rhone, and the streams of Hungary and Transylvania, afford small quantities.

The uses of gold are well known. Alloyed by copper, it is employed for ornamental purposes, coin, and plate. In English coin it was alloyed by two parts of copper to twenty-two of gold; that now used in plate is 18 carats, or $\frac{18}{24}$ths gold. The purple colour used in porcelain painting is obtained from a preparation of gold.

Silver, when pure is ten times heavier than water, and is soft, opake and flexible; a piece one-tenth of an inch in diameter will support two hundred and seventy pounds without breaking.

Silver occurs in the metallic or native state; but is sometimes alloyed by a small proportion of gold, sometimes of copper. It is found in fine filaments disseminated through rocks, but chiefly in veins, in primitive and secondary mountains; occasionally it occurs crystallized in cubes and regular octohedrons, and is accompanied by calcareous and other spars, iron pyrites, cobalt, and some other substances. It is found in Peru, Mexico, Saxony, Bohemia, Norway, Hungary, and England.

The ores of silver are numerous; for although it mostly occurs in the pure state, it is also found combined with gold, copper, antimony, iron, lead, bismuth, arsenic; with the earths, silex and alumine, and mineralized by the *muriatic*, *sulphuric* and *carbonic acids*, and by *sulphur*.

The most common ore of lead, called the sulphuret, mostly contains some portion of silver, but not always worth extracting. The lead of the Westmoreland and Cumberland mines yields an average of seventeen ounces of silver to the ton of lead. The Beeralston mines in Devonshire yield about eighty ounces. The richest

perhaps ever known, was that found at Brunghill Moor, in Yorkshire; which yielded two hundred and thirty ounces to the ton.

According to Helms, the mine of Jauricocha, in Peru, which is about three miles above the sea, contains a prodigious mass of porous brown iron-stone, half a mile long, as much broad, and about one hundred feet in depth, which is throughout interspersed with pure silver; a white argillaceous vein runs through it which is very much richer? It is asserted that Jauricocha, and the mines of the district surrounding it, have yielded forty millions of dollars in a year.

It is said that in 1750, a mass of silver was found in a mine near Freyberg in Saxony, weighing upwards of 140 lbs. and another of about the same size in 1771. In the year 1748, a block of native silver and silver ore was cut out in a rich vein of silver, near Schneeberg; Duke Albert of Saxony descended the mine, and used it as a dinner table. When this huge block was smelted, it yielded 44,000 lbs. of silver. We are told that Annibal received 300 pounds weight of silver, daily, from the mines near Carthagena in Spain.

The mines of Peru and Mexico now furnish annually ten times more silver than all the mines of Europe united.

The uses of silver are numerous, and for the most part obvious. In coin, silver is alloyed by one part of copper to fifteen of silver. The yellow colour used in porcelain painting is oxide of silver.

Mercury or Quicksilver, is thirteen times heavier than water, and is fluid in the natural temperature of the atmosphere.

It mostly occurs pure (but sometimes contains a little silver) disseminated in globules, or collected in the cavities of its mines, which are most commonly situated in calcareous rocks, or indurated clay, or argillaceous schistus.

Quicksilver mines are worked in Carniola, the Duchy of Deux-ponts, Spain and Peru. The vein of Guancavelica in South America, in which quicksilver is found in the state of cinnabar, is 80 Spanish ells in extent, and is situated partly in sandstone, partly in limestone. The cinnabar is accompanied by the sulphuret of lead, calcareous spar, barytes, manganese, arsenic, &c.

The quicksilver mines of Idria, in Saxony, are said to yield 100 tons annually; and those of Spain a still greater quantity. The mines of Peru are said to be still richer.

The ores of mercury are not numerous: combined with silver it is called *native amalgam*, with sulphur and iron, *cinnabar*. *Horn mercury* is a natural combination of mercury mineralized by the *sulphuric acid*, and of mercury mineralized by the *muriatic acid*.

The uses of mercury in medicine, in the arts, and in experimental philosophy are numerous; but its chief use is in the separation of gold and silver from their ores, by a process called amalgamation. When amalgamated with tin, and laid on glass, it forms mirrors.

Lead when pure, is more than eleven times heavier than water; a piece one-tenth of an inch in diameter will hold twenty-nine pounds without breaking.

Lead has never yet been found pure in the natural state. Its ores are numerous, the most common of them occur in beds or veins in almost every mineral district

in the known world, and is perhaps next to some of the ores of iron, the most common of metalliferous ores.

Lead is found in combination with other metals, as antimony, iron, manganese, and silver; and the earths, silex, alumine, magnesia, and lime. It is found mineralized by the *carbonic*, *muriatic*, *phosphoric*, *arsenic*, *molybdic*, and *chromic acids*, and by *oxygen*, which cause it to lose every appearance and character of lead; but many of its ores have not been analyzed.

The most common of the ores of lead is by far of the greatest importance to man, because from it are principally derived the immense quantities of lead for his use. It is called galena or sulphuret of lead; by analysis it yields lead, sulphur, oxide of iron, and sometimes lime and silex; mostly some silver. It occurs in beds and veins in primitive or secondary mountains, most abundantly in argillaceous schistus and secondary limestone, and is accompanied by blende and calamine, the ores of zinc; it is sometimes compact, sometimes crystallized in the cube or regular octohedron.

It would scarcely be possible to enumerate all the valuable purposes to which lead is applied in the arts, in medicine, and in the common wants of man. Among its less obvious uses, lead is employed to glaze pottery, and its oxide enters into the composition of glass. Four parts of lead and one of antimony form printing types, to which by some is added a little copper or brass. With tin and bismuth it forms alloys mentioned in the notice of those metals.

Copper in its pure state, is about eight times heavier than water; a wire one-tenth of an inch in diameter will support two hundred and ninety-nine pounds and a half without breaking.

It is a very malleable and ductile metal, of a pale red colour, with a tinge of yellow. In the natural state it occurs very pure; and its ores are very numerous. In both states it is found in almost every mineral district in the world, in beds, or more commonly in veins, in primitive and secondary mountains, accompanied by several other mineral substances, as the ores of zinc, and occasionally of lead, sometimes of tin; with quartz and fluate of lime and calcareous spar in abundance.

Native or pure copper is not however found either in beds or veins in great quantities; that of Japan and that of Brazil are alloyed by gold. A mass of native copper is said to have been found in a valley in Brazil weighing 2666 Portuguese pounds. Wherever found, it is of various shapes; sometimes it is crystallized in the cube and regular octohedron.

Mineralized by a certain proportion of *oxygen*, it forms a beautiful mineral called the *red oxide of copper*, which assumes a great variety of forms, all of which may be traced into the regular octohedron; with an increased proportion of oxygen it assumes a black hue and is mostly pulverulent.

Copper is found combined with iron, antimony, silver, and arsenic, with lime and silex, and mineralized by the *phosphoric*, *carbonic*, *arsenic*, and *muriatic acids*, and by sulphur, which cause it to lose all metallic character and appearance.

The most common copper ore of the Cornish mines is of a yellow colour, and is called yellow copper ore, or copper pyrites; analysis proves it to consist of copper, iron, and a large proportion of sulphur.

The uses of copper in all its various states are almost endless, and only, if at all, inferior to those of iron.

Alloyed with certain proportions of zinc, it forms brass, pinchbeck, tinsel, and Dutch gold, in imitation of gold leaf. With a small proportion of tin, copper forms bronze or bell metal; but if the proportion of tin amount to one third, it forms speculum metal, used for reflecting telescopes. With zinc and iron, it forms tutenag. In porcelain painting, the green is obtained from copper.

Tin, in its pure state, is about seven times heavier than water, but has never been found pure. In the common ore of tin mines, it is always in combination with *oxygen*, whence it is termed an oxide; but analysis proves it also to contain small portions of iron and of silex.

In one vein in Cornwall an ore has been found called the *bell metal ore*, (from its resemblance to that metal in colour), which consists of *tin*, *copper*, and *sulphur*, together with a small portion of *iron*.

A variety of the oxide of tin, called *wood tin*, from its occasional resemblance to wood, is found sparingly in two or three places in Cornwall only.

Tin is considered to be one of the oldest metals, because it is principally found in the most ancient of those rocks which, from their not containing any animal or vegetable remains, are termed primitive. It occurs disseminated in them, or in beds, but principally in veins, accompanied by the ores of tungsten, arsenic, iron, copper, and zinc, and with quartz, mica, fluate of lime, topazes, and some other substances.

The ore of tin is also abundantly found in Cornwall, in rounded portions or grains, in what are termed alluvial beds; that is, in depositions which have resulted from ruin of rocks.

Tin is by no means one of the most commonly diffused metals. It is most abundant in Cornwall and the western part of Devonshire; but it is also found in Gallicia, in Spain, in Saxony, in Bohemia, in Malacca and Banca in Asia, and in Chili in South America. Two or three small veins have lately been discovered in France.

The alloys of tin with other metals are mentioned in treating of lead, copper, and quicksilver. Another will be noticed under the article bismuth. In a fine leaf, as tin foil, it is used for many purposes; its salts are used in dyeing: its economical purposes are well known.

Iron, when pure, is about seven times heavier than water; it is perhaps the most universally diffused substance in nature, being found in all soils, and in almost every rock.

Iron has been said to have been found in two or three places in the metallic or native state, alloyed by small proportions of lead and copper; but the fact has not been satisfactorily ascertained.

But considerable masses of a substance, which by some is termed *native iron*, have been found in different quarters of the globe; in Bohemia, in Senegal, in South America, and in Siberia; of the latter we have the best account. It was found by professor Pallas on the top of a mountain, on which there was a considerable bed of magnetic iron-stone, on the banks of the river Jenisei. It weighed 1680 Russian pounds, and possessed some of the important characters of pure iron, as malleability and flexibility, and was reported by the inhabitants of the country to have fallen from the sky. The mass found in the Vice-royalty of Peru in South America, was described by Don Rubin de Celis: it

weighed about fifteen tons; it was compact externally, and was marked with impressions as if of hands and feet, but much larger, and of the claws of birds; internally it presented many cavities: it was nearly imbedded in white clay, and the country round it was quite flat and destitute of water.

Most of those masses termed native iron, (which from a current belief of their having fallen from the sky, have also obtained the names of *meteoric iron)* have been subjected to analysis, and in each the iron has been found alloyed with more than one-tenth of the rare metal called *nickel;* which also, it is worthy of remark, is found by analysis to be a constituent part of all those stones, which in various parts of the European Continent, in England, and in America, have been known to fall from the atmosphere, and are therefore termed *meteoric stones.*

The ores of iron are numerous, and are found in beds, in veins, and disseminated in rocks. Iron occurs combined with *manganese*, *carbonate of lime*, *silex*, *alumine*, and *sulphur;* with the *phosphoric*, *sulphuric*, *carbonic*, and *arsenic acids;* but, except when combined with sulphur, iron is always united with *oxygen.* An ore, in which iron is combined with alumine, is used in the making of what are termed *red lead* pencils. Plumbago or *black lead* is a natural compound of iron, with a large proportion of carbon.

It would be vain to attempt the enumeration of the uses to which iron is put by man. Steel is an artificial combination of iron with carbon. The brown colour used in porcelain painting is oxide of iron.

Zinc, when pure, is about seven times heavier than water; its tenacity is not great; a piece one tenth of an inch in diameter will hold twenty-six pounds without breaking; and being far less ductile than some other metals, its importance is thereby diminished.

Zinc is never found pure; its ores are only three in number, but of these some varieties are found. Zinc as an *oxide*, combined with *carbonic acid*, forms a most abundant ore, called *calamine*. Zinc as an *oxide*, combined with *silex*, forms *electric calamine*, so termed from its becoming electric when slightly heated. Zinc combined with *iron*, *sulphur*, *silex*, and *water*, forms that ore called *blende;* a variety of which on being scratched emits a phosphoric light.

The ores of zinc are found in most mineral countries; most abundantly in the transition or earlier secondary rocks, accompanied by iron pyrites, sulphuret of lead, some of the ores of silver, and by calcareous spar and quartz.

Zinc is employed by the Chinese for coins: it enters into the composition of many alloys; (see copper.) It is sometimes used in medicine, and in oil painting.

Palladium, is about eleven times heavier than water; it is very malleable, and somewhat harder than bar iron. It occurs alloying the *native platina* of Brazil, which it greatly resembles in colour; and also in little separate grains, intermingled with those of native platina and very much resembling them: it has never been applied to any use.

Nickel is about nine times heavier than water, and is of a yellowish white; it is not perfectly malleable.

Nickel has never been found in the pure state: its ores are few; they have been found in mineral veins and beds in France, Spain, Bohemia, Siberia, and in England sparingly; they are generally accompanied by the ores of silver and cobalt, by calcareous spar and quartz, and some other substances.

It is remarkable that nickel, which is one of the least abundant metals, has been found by analysis to enter into the composition of those stony substances which in various parts of Europe and America, have fallen from the atmosphere; whence they are termed *meteoric stones.*

The uses of nickel are not numerous; it is chiefly employed in alloys with other metals.

We have now taken a slight view of the eleven metals, which have been termed *perfect*, on account of their possessing the valuable properties of *fusibility*, *ductility*, and *malleability.* I now proceed to those which, not possessing the two latter properties, have been by some termed the *brittle*, or *semi-metals.*

Arsenic is nearly eight times heavier than water, and is of a bluish white.

It is found nearly pure, being alloyed only by small portions of iron and sometimes of gold or silver, chiefly in primitive mountains, in veins, accompanied by some ores of silver, cobalt and lead; by calcareous spar, fluate of lime, and quartz, and some other substances. *Native arsenic* is principally found in certain districts of Germany.

Arsenic, combined principally with *iron*, forms a mineral called *arsenical pyrites*, or *mispickel;* in some of the varieties of which silver is found. This ore principally occurs in veins in primitive mountains.

Arsenic also occurs combined with twenty-five parts of *sulphur*, forming an ore of a red or orange colour, called *Realgar*; and with forty-three parts of *sulphur*, it forms an ore of a bright lemon yellow colour, called *Orpiment*. Realgar is said to occur principally in primitive mountains; orpiment principally in flœtz or secondary mountains.

Arsenic is one of the least useful metals, and though a poison, is used in medicine; it is also used in the making of glass: orpiment is employed as a paint.

Antimony is a compact, brittle, whitish metal, about six times heavier than water. It is found nearly pure, being alloyed only with very small portions of silver and iron. *Native* or pure antimony is found in veins in the mountains of Dauphiné, in the Hartz, &c. and in Sweden, disseminated in calcareous spar.

The ores of antimony are only four in number; all of which have not been analyzed. In some of them, it occurs combined with oxide of *iron*, *cobalt*, *arsenic*, *silex*, *sulphur*, *oxygen*. They are found principally in veins in primitive, and in transition, or the older secondary, mountains in Sweden, Saxony, France, Bohemia, England, and other mineral countries.

Antimony forms alloys with other metals, and is used in the arts. It enters largely into the composition of printing types: it is also used in medicine.

Bismuth is nearly 10 times heavier than water; it is of a reddish-white colour, and very brittle.

It is found in the *native* state somewhat alloyed by arsenic.

The ores of bismuth are only two in number; in that

called *sulphuret of bismuth*, it is combined with *sulphur;* in the other, called *bismuth ochre*, it is mineralized by *oxygen*, and combined with small portions of *oxide of iron*, and *carbonic acid.*

Native bismuth is rare, as well as its ores; these are found in veins, mostly in primitive mountains, accompanied by the ores of cobalt, of iron, of zinc, and sometimes of silver, and by quartz, calcareous spar, and barytes; in Bohemia, Transylvania, France, and Sweden. The sulphuret of bismuth has occurred in Cornwall.

Bismuth is very little used, but it enters into the composition of some of the soft solders, and of sympathetic ink. It forms alloys with other metals. Tin and bismuth are two of the most fusible metals. The fusible metal of Sir Isaac Newton is composed of 8 parts of bismuth, 5 of lead, and 3 of tin; when this is thrown into water, and heat applied, it melts a little before the water has reached the boiling point.

Cobalt, when pure, is about 8 times heavier than water: it is of a grey colour, with a red tinge, and has the magnetic properties of iron.

It is not found pure. Its ores are not numerous. In one of them from Tunaberg in Sweden, it is combined with *arsenic* and *sulphur;* and somewhat resembles iron pyrites in form and colour. In Cornwall, Bismuth is found combined with *arsenic* and *iron.* Its other ores have not been analyzed, but cobalt seems always to be combined with arsenic.

The ores of cobalt occur in veins both in primitive and in secondary mountains: they are mostly accompanied by some of the numerous ores of copper, sometimes by na-

tive bismuth, native silver, native arsenic, and the ores of silver.

Cobalt is very little used except in the arts. It is brought to this country reduced to the state of an oxide, of an intense blue colour, called *zaffre*, which when melted with 3 parts of sand and 1 of potash, forms a blue glass, and when pounded very fine is called *smalts*, and is then employed to give a blue tinge to writing papers, and in the preparation of cloths, laces, linens, muslins, &c.; for colouring glass, and for painting blues on porcelain. So intense is the blue of zaffre, that one grain will give a full blue to 240 grains of glass.

MANGANESE is of an iron grey colour, very brittle, and seven times as heavy as water: it is difficult to be obtained in the metallic state.

It is never found pure. Its ores are not numerous. It occurs combined with the *oxide of iron*, with *sulphur*, the *sulphuric* and *carbonic acids*, and with *barytes*; but most abundantly with *oxygen*, as an oxide, of a brown colour or black.

The ores of manganese are found in various parts of the continent of Europe, and in the mineral districts of Britain.

From the black oxide of manganese, all the oxygen gas used by the chemist is obtained, and all the oxygen entering into the composition of the oxymuriatic acid consumed in the bleacheries of Britain, France, and Germany. The violet colour employed in porcelain painting is obtained from manganese. In glass-making, it is employed in the finer kinds of glass, both as a colouring material and a destroyer of colour: this application of it is ancient; it is mentioned by Pliny.

Tellurium when pure, is about the colour of tin. It is brittle, nearly as fusible as lead, and is six times heavier than water.

It is an extremely rare metal, and is found in the native state, but always alloyed by iron and gold, principally in veins traversing secondary rocks in Transylvania. In one of its ores, called *graphic tellurium*, it is combined with *gold* and *silver;* in the other, which is called *plumbiferous tellurium*, it is united with *lead*, *gold*, *silver*, and *sulphur*.

It has never been made any use of.

Titanium is so difficult of fusion, that the attempts to reduce it to a pure metallic state have scarcely succeeded. It is of a copper red colour.

Two of its ores are said to be nearly pure *oxides*. In others, Titanium is in combination with oxygen and also with *oxide of iron*, of *uranium*, and with *silex*. They occur sparingly in Hungary, Transylvania, France, Britain, and North and South America.

The hair-like appearances sometimes to be observed in crystals of quartz, are mostly crystals of titanium. An ore of titanium is found in a stream in Cornwall in black grains; another is found in Transylvania resembling yellow sand.

The only use to which titanium has ever been put, was in the porcelain manufactory at Sevres, where it was employed to produce the rich browns for painting it. The want of uniformity in colour, occasioned its disuse.

Tantalium is a metal, having but a slight external metallic lustre; it is dull and almost black internally.

It is extremely rare; having hitherto only been found

in Finland and Sweden. In Finland, it occurs combined with *oxide of iron* and of *manganese*, forming a mineral called *tantalite*, imbedded in quartz, in veins that traverse a red granular felspar. In Sweden, it is found in a mineral which is called *yttrotantalite*, because analysis has proved it to be principally composed of the rare earth *yttria*, and the rare metal *tantalium*. This mineral occurred in a granite rock.

Molybdena, when pure, is of a greyish white, and in the form of brittle infusible grains.

It is very rare, and has never been found pure. Combined with *sulphur* it occurs in veins in primitive mountains in Norway, Sweden, Saxony, Switzerland, and Britain, accompanied by tin, wolfram, quartz, and mica.

The *molybdic acid* has been found combined with *lead*, forming a mineral called *molybdate of lead*, in Carinthia, Saxony, Hungary, and Austria ; it is accompanied by calcareous spar, sulphuret of lead, the ores of zinc and fluor spar.

Molybdena has never been applied to any use.

Tungsten is a hard, brittle, granular metal, of a light steel-grey colour, and brilliant metallic lustre.

It is not found pure ; but only in the state of an oxide, or of an acid combined with other substances.

The *oxide of tungsten*, combined with *lime* and *silex* has been sparingly found in Sweden, Bohemia, and Cornwall. The compound is called *tungstate of lime*.

The tungstic acid, combined with *oxide of iron*, *manganese*, and *silex* forms a mineral called *tungstate of iron*, or *wolfram*, which occurs in most districts in which tin is found.

The only use to which tungsten has hitherto been applied, is in the arts, as forming, in combination with other substances, those red paints known by the name of lake.

Chrome is a metal of a greyish-white colour and extremely brittle: it is worthy of note that like the foregoing metal it has not been found in the *metallic form*, but only in the *acid state*, or in that of an *oxide*.

The *chromic acid* in combination with *lead*, forming a compound mineral called *chromate of lead*, has been found principally in veins in gneiss and mica-slate, in a gold mine in the Uralian mountains in Siberia: it is said also to have occurred at Annaberg in Austria, and at Trapettes in Savoy. It is extremely rare.

The *oxide of chrome*, in combination with *oxide of iron*, *alumine* and *silex*, forms a mineral called *chromate of iron*, which is found in France, and in some places in Siberia.

The chromate of lead, on account of its beautiful red colour, has been employed in Russia as a paint. Chrome, as obtained in the metallic state by the chemist, from either of the two foregoing compounds, has not been applied to any important use: it tinges glass of a green colour. It has been ascertained that the emerald owes its beautiful green colour to *oxide of chrome:* it seems therefore probable that chrome may hereafter be employed as a paint.

Osmium,
Iridium, and
Rhodium are three brittle metals which, together with Palladium, already noticed as a malleable metal,

have by analysis been found in combination with Platina in the crude state. Osmium and iridium also occur, forming together a natural alloy, in small grains, intermixed with the grains of platina. Not one of these four metals has hitherto been applied to any use.

Uranium is a brittle, granular, hard metal, of extremely difficult fusibility.

This metal has never been found in any state having a *metallic* appearance; consequently never in the pure state. Its ores are only two; they are rare. They have been found in Saxony, Bohemia, Norway, France, and England; in the latter only in copper veins.

Uranium is found only in combination with *oxygen*, forming an *oxide* called *Uranite;* or with *oxygen* and *oxide of iron*, when it is called *uran-ochre.*

The oxide of uranium is a beautiful mineral, mostly in small thin plates of a fine green colour, and transparent: in combination with oxygen and oxide of iron, uranium forms a mineral similar in appearance to pitch; or sometimes resembling iron-rust.

No use has hitherto been made of uranium.

Cerium has hitherto only been obtained from two or three mineral substances, in the form of a white, yellowish, or reddish brown powder: yet although cerium has never been obtained in the metallic form, it is considered from its properties to be a metal.

In the *Cerite*, which has been found only in Sweden, Cerium is combined with oxygen, iron, silex, lime, and water.

In the *Allanite*, which was found in Greenland, and

in another mineral from the Mysore, Cerium is combined with oxygen, iron, lime, silex, alumine, and water.

It has not been applied to any use.

We now proceed to the consideration of those mineral bodies which from their peculiar properties are termed COMBUSTIBLES. These form, in the mineral kingdom, a class of substances by no means agreeing amongst themselves in internal or external characters, and differing essentially from the earths, the alkalies, and the metals. Combustibles include both the hardest and the softest of mineral substances.

Most of the metals whose properties are altered by combustion, acquire an *increase* of weight thereby; whereas combustible substances are sensibly *diminished* in weight by the same process. The product of some of them is liquid, of others, solid; if solid, it is insoluble in water.

The *mineral bases* of combustible substances may be said to be only two, viz. CARBON and SULPHUR.

Combustible substances may be comprized in the following list:

Sulphur	*Coal*
Diamond	*Jet*
Mineral Carbon	*Amber*
Plumbago, or Graphite	*Mellite, or Honey Stone*
Mineral Oil	*Retinasphalt*
Bitumen, or Mineral Pitch	*Fossil Copal*

SULPHUR, is a soft, brittle substance of a pale yellowish colour. It is found either nearly pure, or in combination with certain metallic ores, in great abundance.

It is also found both in the vegetable and animal kingdoms.

The DIAMOND, which is the hardest substance in nature, was heretofore considered as an earthy or stony substance; but it is proved beyond a doubt not to be an earthy substance. When exposed to a current of air and heated to the temperature of melting copper, it is found to be gradually, but *completely* combustible. By this process it may be wholly converted into carbonic acid, and therefore consists of *Pure Carbon*.

Diamonds are either colourless, or of a yellowish, bluish, yellowish green, clove brown, black brown, prussian blue, or rose red colour:—they are naturally found in detached crystals, the primitive form of which is the regular octohedron. In India, diamonds are found in an indurated ochrey gravel. The diamond mines extend through a long tract of country, from Bengal to Cape Comorin: the chief of them are now between Golconda and Masulipatam. Diamonds are also procured from the Isle of Borneo and from Brazil, where they are found in beds of ferruginous sand or gravel.

The largest diamond hitherto found, is in the possession of the Rajah of Mattan, in the island of Borneo, in which island it was found about 80 years ago. It is shaped like an egg, with an indented hollow near the smaller end. It is said to be of the finest water. It weighs 367 carats. Now as 156 carats are equal to 1 oz. Troy, it is obvious that this diamond weighs 2 oz. 169.87 gr. Troy. Many years ago the governor of Batavia tried to purchase this diamond. He sent a Mr. Stuvart to the Rajah, who offered 150,000 dollars, two large war brigs with their guns and ammunition, together with a certain

number of great guns, and a quantity of powder and shot. The Rajah, however, refused to deprive his family of so valuable an hereditary possession, to which the Malays attach the miraculous power of curing all kinds of diseases, by means of the water in which it is dipped, and with which they imagine that the fortune of the family is connected.

The principal use of the diamond is in ornamental jewellery; it is also employed by glaziers to cut glass, and by lapidaries to engrave the harder gems.

Mineral Carbon, or Charcoal, is greyish black. It occurs in plates or irregular pieces, in various sorts of common coal. It has a glimmering, silky lustre, and a fibrous appearance, discovering a wood-like texture. It is somewhat heavier than common charcoal, and is easily reduced to ashes before the blow-pipe, without either flame or smoke.

Plumbago, or Graphite, is found in England, Scotland, France, Spain, Germany, and some other countries. Plumbago is of a dark iron black, passing into steel grey; it has a glistening metallic lustre.

The principal use of plumbago is in the making of what are called *black-lead* pencils; for which purpose none has yet been discovered equal to that from Borrodale in Cumberland, where it occurs in a considerable mountain of argillaceous schistus.

Whence this mineral obtained the name of *black-lead* it is difficult to say, unless it was from the lead-coloured streak which it gives upon paper. It has been ascertained that lead does not enter into its composition, but that the purest plumbago consists of about 90 parts of carbon and 10 of iron.

Mineral Oil. Under this term are comprehended two substances, *naptha* and *petroleum*; both of which are liquid, highly inflammable, and lighter than water.

Naptha is nearly colourless and transparent; it gives out much smoke and a penetrating odour in burning. The most copious springs of naptha are on the coast of the Caspian sea. It is employed externally for strains and bruises. The Persians and Russians are said to take it as a cordial.

Petroleum, at the usual temperature, is rather thicker than common tar, and has a strong, disagreeable odour. It is principally found in coal countries, as in Colebrookdale. It is also found in France, Italy, Switzerland, Germany, Hungary, and Sweden.

It is most plentifully found in Asia: round the town of Rainanghong in the Birman empire, there are 520 wells in full activity, into which petroleum flows from over coal. No water ever penetrates into these wells. The quantity of petroleum annually produced by them amounts to more than 400,000 hogsheads. To the inhabitants, its uses are important; it serves instead of oil for lamps, and, mixed with earth or ashes, for fuel.

Bitumen, or Mineral Pitch, is either *elastic* or *compact*.

Elastic Bitumen is of various shades of brown. It has a slightly bituminous odour, and is about the weight of water. It burns readily with a large flame and much smoke, but melts by a gentle heat, and is thereby converted into a substance resembling petroleum.

Hitherto it has only been found in the Odin mine, near Castleton in Derbyshire, in a secondary limestone.

Compact bitumen is of a brownish-black colour; one variety may be impressed by the nail, and is called *maltha;* another is very brittle, and is called *asphalt.*

They consist of carbon, hydrogen, earth, and bituminous oil.

The softer variety has not been put to any use; but the harder is used in varnishes, and is an essential part of those used by engravers. It is found on the shores of the Dead Sea, in the West Indies, and many other places.

The ancients employed bitumen in the construction of their buildings; and it is said that all historians agree that the bricks of which the walls of Babylon were built, were cemented with hot bitumen; which gave them very great solidity. Bitumen was carried down by the waters of a river which joined the Euphrates; it was also found in the salt springs in the neighbourhood of Babylon. The Egyptians are also said to have employed it for the embalming of bodies; constituting what now we call mummies.

Coal. The bituminous substance called coal, though ranked among minerals because its basis is pure carbon, is now by many believed to be of vegetable origin; because the substance which lies upon the coal, is always filled with vegetable remains; as well as because a wood-like appearance may be traced through every species of coal, even the most compact.

On the subject of coal deposites, particularly our own, it is my intention to treat more at large.

Coal may be divided into three species: *brown coal, black coal, cannel coal, and glance coal.*

Brown coal is imperfectly bituminous; in all its va-

rieties it is fibrous, and in some of them its vegetable origin is so complete, as that the remains of the trunks and branches of trees are visible and almost perfect. Brown coal burns with a weak flame and disagreeable odour. It is found in horizontal strata. In England it occurs at Bovey, near Exeter, and is called Bovey coal. It is also found in other countries.

Black coal, which is used for economical purposes, includes several varieties. It may, however, generally be said to be of a black colour, having an iridescent tarnish, and a high resinous lustre. It is composed of about 60 parts of carbon and 36 of maltha and asphalt, and 3 to 6 per cent. of earth and oxide of iron. It always occurs in nearly horizontal strata, which are abundant in Durham, Lancashire, Yorkshire, and in some other parts of England, and in several parts of Europe.

Cannel coal is chiefly found at Wigan in Lancashire, but is more or less abundant in most collieries. It is very brittle, of a shining lustre, it crackles and flies while burning, flames much and burns quickly, leaving only 3 or 4 parts in the 100 of ashes.

Glance coal, or *Blind*, or *Kilkenny coal*, or *Anthracite*, is of a dark iron black, and has a bright, metallic lustre. It burns without smoke, and emits no sulphureous or bituminous odour. It consists of pure carbon, with some silex or alumine, and a small portion of oxide of iron.

Jet, or *Pitch coal* is generally of a velvet black; it occurs in mass, and sometimes in the shapes of branches, with a regular woody structure. It has a brilliant, resinous lustre. It is used as fuel, but the finer and harder pieces are worked into trinkets, under the name of jet. It is found in the Prussian amber mines in detached fragments, and is there called black amber.

Amber is a mineral of a yellow, or reddish-brown, or of a greenish or yellowish white colour. It is found in nodules or rounded masses, from the size of coarse sand to that of a man's head.

Amber is found on the shores of the Baltic, of Sicily and of the Adriatic Sea, and occasionally in the gravel beds near London. Near the sea-coast in Prussia, there are regular mines of amber: under a stratum of sand and clay about 20 feet thick, succeeds a stratum of trees, 40 or 50 feet thick, half decomposed, impregnated with pyrites and bitumen, and of a blackish-brown colour. Parts of these trees are impregnated with amber, which sometimes is found in stalactites depending from them. Under the stratum of trees were found pyrites, sulphate of iron and coarse sand, in which were rounded masses of amber. The mine is worked to the depth of 100 feet, and from the circumstances in which the amber is found, it seems plain that it originates from vegetable juices. Amber sometimes incloses insects, believed to be of the ant species. The strong electric powers of amber are generally known.

The origin of amber is not perfectly understood; it is generally considered to be a fossil resin somewhat mineralized.

Amber yields by distillation an acid called the *succinic acid*, and leaves as the residue an extremely black, shining coal, which is employed as the basis of the finest black varnishes. When exposed to flame in the open air, amber takes fire and burns with a yellowish flame, giving out a dense, pungent, aromatic smoke, and leaving a light, shining, black coal.

The MELLITE or HONEYSTONE is a rare mineral, having hitherto only been found in Thuringia, in the district of Saal, and in Switzerland. It occurs on bituminous wood, and earthy coal, and is generally accompanied by sulphur.

The honeystone is softer than amber, is transparent, brittle, and electric, and is found crystallized in the octohedron.

When burnt in the open air, neither smoke nor flame are observable, and it eventually acquires the colour and consistence of chalk. By analysis it gives a peculiar acid, called the *mellitic acid*, in combination with alumine, together with small portions of iron and silex.

RETINASPHALT has been found at Bovey in Devonshire in opake lumps of a yellowish colour, adhering to Brown Coal. It is brittle and soft, and consists of resin, asphalt and earth.

FOSSIL COPAL, or HIGHGATE RESIN, was found in little masses of a dirty brown colour, and brittle. In the flame of a candle it takes fire, and before the blowpipe burns entirely away. It was found in the blue clay of which Highgate hill consists.

We have now concluded the subject. What has been said was intended only to convey a slight outline of the elements of Mineralogy. There exists a vast multitude of mineral compounds which it was not possible to offer to your notice in so short a space of time, and which involve many inquiries and researches belonging more properly perhaps to the mineralogist in his closet.

It may be observed that although we should now have

been ignorant of the existence of some of the earths and metals, but for the researches of the chemist, yet the properties and uses of by far the greater number of those which are most useful to man, were known and employed in his service long before chemistry was pursued as a science. Perhaps not one half of the earths, metals, and combustibles, have in any important degree been hitherto turned to advantage.

LECTURE III.

Of the objects of Geological enquiry—Hypotheses—Geological positions—Of the low and level parts of the Earth—Of the chalk basins of Paris, of London, and of the Isle of Wight.

It was said on a former evening that the object of mineralogy is the study of mineral bodies in *particular*, whether simple or compound: that geology embraces the study of the globe *in general*, and of the various relations that the different masses of which it is constituted, bear to each other. Mineralogy may be therefore said to furnish, as it were, the alphabet to geology.

The globe we inhabit is about 8000 miles in diameter, 25,000 in circumference. Its surface has two grand divisions, land and water: one-third, or thereabouts, being occupied by land, and two-thirds by water.

So little was known by the ancients respecting the earth, (of its real form and unceasing revolutions they were absolutely ignorant), that it was by them considered to be the center of the universe; of which, a more correct philosophy has proved it to be only a subsidiary portion. It is not therefore to be wondered at, that in the pursuit of our present object, we derive little or no benefit from the writings of ancient authors. In the time of Herodotus the Greek historian, it may however be inferred that there existed some philosophers who imagined that the earth was round, and that it was

encompassed by the sea, since the historian takes the opportunity of ridiculing the opinion.

Until towards the end of the last century, geology was little understood; perhaps because those sciences on which it greatly depends, chemistry and mineralogy, had not made any large advances towards their present state. It is no marvel therefore that in default of a knowledge of these sciences, and of that research by which alone we can become acquainted with the constituent masses of the globe, the activity of the human mind should attempt to account for the creation and present state of the earth by uninstructed efforts of the imagination. It may be amusing to give a short account of a few of these imaginary theories.

In these hypotheses, two events only, the creation and the deluge, seem to have entered into the calculations of the inventors, as comprehending all the changes to which the globe has been subjected: that is to say, each arbitrarily ascribed to it a certain primitive state, which each supposed to be altered and modified by the effects of the deluge.

In the opinion of *Burnet*, the whole earth at first consisted of an uniform light crust, which covered the abyss of the sea; and which, being broken for the production of the deluge, formed the mountains by its fragments.

According to *Woodward*, the deluge was occasioned by a momentary suspension of cohesion among the particles of mineral bodies; the whole mass of the globe was dissolved, and the soft paste became penetrated by shells.

Whiston fancied that the earth was created from the atmosphere of one comet, and deluged by the tail of another.

The great *Leibnitz* amused himself, as did also *Descartes*, by conceiving the world to be an extinguished sun or vitrified globe; upon which the vapours, condensing in proportion as it cooled, formed seas, which afterwards deposited calcareous strata.

Demaillet conceived the globe to have been covered with water for many thousand years; that it gradually retired; that all the terrestrial animals were originally inhabitants of the sea; that man himself began his career as a fish.

Buffon imagined that the mass of our earth, together with those of the other planets, were struck off the sun, in a liquified state, by a comet, at the same instant.

Some modern philosophers have supposed every thing to have been originally fluid; that this universal fluid gave existence to animals of the simplest kind; that in process of time the races of these animals became complicated, and dying, supplied calcareous earth or lime; that aluminous earth or clay was supplied by the decay of vegetables. That these two earths were re-dissolved, and finally converted into silex; hence that the more ancient mountains are siliceous. Thus the solid parts of our globe, according to these visionaries, owe their existence to animal or vegetable life; and without it would have continued entirely liquid.

Kepler, one of the greatest of astronomers, considered the globe to be possessed of living faculties and a circulating vital fluid; that all the particles of it are alive and possess instinct and volition, whence their attraction and repulsion: that the organs through which the huge animal breathes are the mountains; that mineral veins are abscesses, and metals the products of rottenness and disease.

These systems, and even many more than these, have had their admirers, and have successively sunk into disrepute and neglect in proportion to the advance of chemical and physical science. It is the apology, if indeed it be not rather the shame of their inventors, that they knew little of mineralogy, or of the structure of the earth. Two or three theories of a date much later than the foregoing—of the end of the last and beginning of the present century,—are worth notice. Marschall supposes the fragments of which the surface of the earth is composed to have fallen from heaven. Bertrand has supposed that the earth is hollow, and contains within it a load-stone, which is dragged from one pole to the other by the attraction of comets; so as, by changing its center of gravity, to drown alternately the two hemispheres. Jameson, now a professor of natural history in one of our own universities, has lately published this amusing query; 'As the true figure of the earth is still unascertained, may we not conjecture, from what is already known, that it is a polyedron (a figure of many sides), and that the strata, under determinate angles, form the sides and cleavage of this great crystal?'

If philosophers, and even naturalists, will still condescend to amuse the world with conceits like the foregoing, it is no wonder that the present period, with respect to the theory of the earth, should have been said to bear some resemblance to that, in which some philosophers thought that the heavens were formed of polished stone, and that the moon was no larger than Peloponnesus. Almost equally absurd, they merit equal notice as examples of extravagant theory; but they convey to us at the same time this instructive lesson, that it

is *only by the patient investigation of facts and of natural phenomena*, that we can hope to approach the truth, in the sublime study of the history of the planet we inhabit.

Within the last few years mineralogy has made advances so rapid, as well as other investigations connected with the history of the earth, that geology is thereby greatly raised in rank among the sciences. A review of modern researches and discoveries will strikingly evince the folly of any attempt to account, by a turn of the pen, for the creation of the globe, or for the revolutions to which it has been subjected: these researches amongst the phenomena of the earth will also assure us, that in whatever manner the mighty display of Omnipotence in its creation was effected, it has since suffered great changes on its surface.

It is probable that chemistry will yet make great alterations in the catalogue of elementary substances, either by addition or diminution; most probably by the latter. We shall however assume those which have already been enumerated, (page 3,) according to the present state of our knowledge, to be *the constituents of which the various masses of the crust of our globe are compounded;* but, whether the globe is to its very center a mass of these compounds, we know not: and since there seems no probability of our arriving at any certainty on this head, let us forbear to conjecture. It is the business of the geologist to investigate the *natural facts and phenomena* within our reach; and let us be assured that when these fail to accomplish any desirable purpose, we shall add nothing to our knowledge by soaring into the regions of fancy. On a former evening it was said that as the miner rarely descends below

$\frac{1}{30000}$th part of the earth's diameter, so, if we suppose the earth in shape to resemble an orange, it may be said that we know nothing but of the outer rind.

Geology, therefore, in the present true sense of the term, embraces little more than an *inquiry into the history and present state of the surface or crust of the globe.* Disclaiming theory, it is my purpose to adhere to the legitimate objects of science, as they have been just described, without exerting one pretension beyond them.

Much has been written on the subject of the creation; a subject so far beyond our limit, that upon it I shall be silent; nor shall I attempt to follow Kirwan through a laborious undertaking to reconcile our *partial knowledge* of the phenomena of nature, and of the constituent masses of the globe, with the Mosaic account of the creation. If ever it should be permitted that man shall comprehend the great plan by which the Creator reduced to order the materials of which the globe is composed, with the same certainty as he has attained a knowledge of the mechanism of the universe, some more certain data and discoveries will be allowed to him, than as yet have fallen to his lot. Geology is yet in its infancy: shall we not therefore do wisely in concluding that we are not in the possession of materials sufficient for the investigation. We have no reason to disbelieve that this important branch of geological inquiry will hereafter be better understood. Considering the present state of our knowledge, we shall be best and most reasonably employed in the investigation of the present state of the earth, and of the changes to which its surface has been subjected; taking as our text the incontrovertible truth, that 'In the beginning God created the heaven and the earth.'

Some of the most acute geologists of the present day, have not yet agreed whether the *agent* employed in the magnificent work of reducing to order the heterogeneous mass of elementary substances, was *fire* or *water*. There exist at this moment two distinct parties, distinguished according to the notion they embrace, by the appellations of *Volcanists* and *Neptunists*. Each loudly asserts the preference of its own theory; each being in the possession of chemical facts, or of natural phenomena, which establish in its separate opinion its own claim to preference, that have not been controverted by the other. Distinct however, from these two parties, there are many who wisely think that we are yet too ignorant to be able with propriety to establish any theory at all. These are collecting evidence in regard to its actual state from every quarter of the globe, which if faithfully recorded, may hereafter enable mankind more nearly to approach the truth than at present it is possible.

To the results of these inquiries, in so far as they have proceeded, it is my present object to invite your attention. They will comprehend much on the consequences of the catastrophes that have befallen the surface of the earth by the agency of water; of which we have abundant and incontrovertible evidence: inquiries into the nature and component masses of mountains, and of their relative heights; the internal structure of the earth; mineral veins; the deposites of salt and of coal; and of volcanoes.

These are inquiries well meriting our attention; they will exhibit to us the investigations of men, who, being philosophers in the true sense of the word, have sought and still continue to seek among the instructive records

of revolving ages, amid the ruin occasioned by time and circumstance, the history of the globe we inhabit.

He who resides in a country which exhibits an almost perpetual verdure, uninterrupted by barren rocks, or desolate regions, and has never visited any other, will scarcely suspect that the surface of the globe has been much convulsed by successive revolutions and various catastrophes. If however he descend to any considerable distance beneath its surface, or ascend the hills that border the plain, he will be likely to receive a new train of ideas; his mind will become expanded in proportion to the expansion of his view. But if he ascend the elevated chains of mountains, or follow the beds of descending torrents, which lay open their interior structure, he will become prepared to believe to the full extent, that various catastrophes have befallen the globe since its creation.

We reside in such a country; a country of perpetual verdure, uninterrupted by a single rock, or one desolate place. The elevations that surround us scarcely merit the name of hills; and being all alike verdant, they admit not of investigation, beyond what is attained in the sinking of wells. Few of us have visited other countries; not many have seen the more mountainous part of our own; scarcely one present, perhaps, knows the internal history of the spot which now supports him. We generally know that it principally consists of clay, even to a considerable depth; but the greater part have yet to learn that this clay has unquestionably been deposited by the sea, that it encloses sea-shells, and that the whole country surrounding us to a considerable depth and extent, consists of the *debris*, or ruin of rocks.

It seems to me that we cannot do better than begin our inquiries into the nature of such countries as those in which *we* live—of low and level countries; from which we may rise to the consideration of such as are somewhat more elevated, and thence to that of the nature and component masses of mountainous regions.

But level countries are so little open to the investigation of the geologist, and seem to afford, when compared with the more obvious masses of mountains, so little to attract his attention and research, that the nature of the larger tracts of such country is but little understood. Mineral beds and veins are for the most part situated in hills, or eminences of more considerable elevation; to these therefore the attention of the miner and the mineralogist, as well as of the geologist, has hitherto been principally directed: the component masses of mountains are known the best. During the short period that mineralogy and geology have ranked among the sciences, they have made rapid advances: within the present century considerable attention has been given to the exploring of some tracts of level country, which have amply paid the research. From the actual nature of these, we may reason by analogy of the rest.

In Europe, the principal tracts of low or level country are the eastern parts of England, the Netherlands, and the northern parts of France and Germany, and the whole of Poland. In Asia, the north-east parts of Russia, called the Steppes. In America, there are vast tracts of low land, through which the Mississippi and Missouri rivers take their course. The extent of the low lands of Africa is not ascertained.

From what is actually known, however, it may be

asserted that *the lowest and most level* parts of the earth, when penetrated to a considerable depth, exhibit horizontal strata, composed of various substances, and containing, almost all of them, innumerable marine productions. Similar strata, with the same productions, compose the *hills* even to a considerable height. The shells are sometimes so numerous as to constitute the entire body of the stratum; they are often in so perfect a state of preservation as that their sharpest ridges are retained: they are found in elevations far above the level of the ocean, and in places to which the sea could not be conveyed by any existing cause: they are sometimes enclosed in loose sand, sometimes filled or penetrated by the hardest stone. Every part of the earth, every continent, and almost every island, exhibits the same phenomenon.

It was once, long ago it is true, asserted that these remains of shells, and other organized bodies, were merely the *sports of nature;* but it has been frequently found that the nicest and most scrupulous comparison of their forms, cannot detect the slightest difference between some of these shells, and the shells which still inhabit the sea. They have therefore once lived in the sea, and been deposited by it; the sea must consequently have rested in the places where the deposition has taken place. Hence it is evident that the basin or reservoir containing the sea has undergone some change at least, either in extent, in situation, or in both.

The traces of revolutions become still more apparent and decisive if we ascend a little higher, and approach nearer to the foot of *great chains of mountains;* still many beds of shells are found, some even larger and more solid, quite as numerous and well preserved, but

not of the same species as those found in less elevated regions. Here the strata that contain these shells, are of various degrees of inclination, and sometimes instead of being horizontal, as in plains and low hills, are even vertical. The strata of great chains of mountains, of whatever composed, or however placed, are laid open to view by means of vallies which time and violence have produced.

The diversity existing in the inclination of strata, clearly point out, in the estimation of many geologists, that by some means these have been broken and overturned.

The operation of an agent equal to the breaking up and overturning of the strata of mountains, and, if I may so say, to the destruction of rocks, and to the forming anew whole tracts of country which enclose the remains of organized bodies, was, it cannot be doubted, equal to the disruption of vast portions of continents, thereby forming islands : and it must in all probability have almost universally changed in appearance and even in form, the surface of the globe.

It is beyond a doubt that there have been many catastrophes of the *same nature*, though not perhaps of equal extent. What has been the agent employed in the production of these catastrophes, is most obvious. It is not to be doubted that there have been successive irruptions and retreats of the sea ; and it seems equally certain that the final result has been the universal depression of its level.

As we ascend to still higher points of elevation, and advance towards the *summits of mountains*, the remains of marine animals, and that multitude of shells already spoken of, begin to grow rare, and at length disappear

altogether. We arrive at strata of a very different nature, which contain *no vestige* of living creatures; nevertheless, certain circumstances observable in all these strata, in which not a trace of organic remains is to be found, have induced some geologists to suppose that their bare and rugged summits, though elevated far above the strata containing shells, have also been moved or overturned.

But though, by some, these rocks are not considered to be precisely in the place and position in which they were originally deposited, they are nevertheless considered by all geologists to be of older formation than all other rocks; because they contain no animal remains, and because the rocks which enclose such remains, rest upon, but are never found under, such as do not contain them. They have therefore been called *Primitive Rocks.*

Rocks of this description rise through others at various elevations in every quarter of the globe; but in their greatest elevation, *primitive mountains* traverse our continent in various directions, rising above the clouds; separating the basins of rivers from each other, and serving, by means of their perpetual snows, as reservoirs for feeding springs; and forming, in some measure, the skeleton, or, as it were, the rough frame-work of the earth.

I shall here recapitulate what has just now been said; and shall afterwards proceed to its elucidation, by adducing such proofs, drawn from the observations of men who have made the phenomena of the globe their study, as may be consistent with the nature of the subject and our present object.

1. That the *lowest and most level* parts of the earth consist of *horizontal strata*, composed of various substances, many of them containing marine productions.

2. That *similar, but variously inclined, strata* are found *in hills* to a great height.

3. That shells are sometimes so numerous as to constitute entire strata.

4. That shells are found in elevation *far above the level of the sea*, and at heights to which the sea could not be raised by any existing cause.

5. That these shells once lived in the sea, and were deposited by it.

6. That shells continue to be found as we rise to the foot of *great chains of mountains*.

7. That at this elevation, the strata, instead of being horizontal as in plains, are of *various degrees of inclination*, and sometimes *vertical*.

8. That from these and other circumstances it is inferred that there have been frequent irruptions and retreats of the sea.

9. That as we approach the *summits of lofty mountains*, their strata become wholly different, the remains of marine animals and shells become rare, and even disappear altogether.

10. That even these strata are, by some, considered not to be precisely in the position in which they were formed.

11. That, as they contain no vestige of animal remains, they are considered to be the oldest rocks, and therefore are called *primitive*.

The consideration of these points will naturally involve inquiries into others which may be termed sub-

sidiary to them. In order however to form a complete outline of Geology, it will be necessary to add to these a number of other inquiries, more within the province of the mineralogist. Of these I shall now present an outline; and after attempting an elucidation of the foregoing, I shall in like manner proceed with these, and present to your notice the experience and observations respecting them, of men who have studiously investigated the phenomena of the globe.

12. That rocks, which, because they include no vestige of animal remains, are termed *primitive*, are of various kinds.

13. That rocks enclosing animal remains, are never found underneath, or supporting, those rocks which are termed *primitive*.

14. That some primitive rocks alternate with each other, but that granite is found beneath all others, and frequently overtops all the rest.

15. That rocks which include organic remains, must have been formed *after* the shells they contain; and *therefore*, not being considered *primitive*, they are by some termed *secondary rocks:* whence the terms, used by geologists of *primary* and *secondary formations*.

16. That there are many varieties of *secondary* rocks, each of which has received a geological appellation.

17. That there exists another class of substances not appropriately termed *rocks;* but which, being considered to be the *debris* or ruin of rocks, by their long exposure to the action of air and water, or both, are therefore termed *alluvial deposites*.

I now proceed to the illustration of the first position, viz.

That the lowest and most level parts of the earth consist of horizontal strata, composed of various substances, many of them containing marine productions.

The illustration necessary to this position will include many of the newest, most striking, and most important geological facts. These facts will prove, to a limited extent, another of our assertions, namely, that the catastrophes to which the surface of the globe has been subject have been numerous: and it will be shewn that some of these have not been owing to irruptions of the sea, but to the agency of fresh water; and it will clearly appear that these irruptions of *fresh and salt water* have been *alternate*.

In order to make the whole of these circumstances more intelligible, it will be requisite a little to anticipate, by adverting, here, to some geological facts, which, according to our previous arrangement, would belong to another place. Geologists who have had ample opportunity of examining mineral deposites in large and mountainous tracts of country, have satisfactorily ascertained that certain deposites are always found *beneath*, *never above*, certain other deposites. Investigation has proved that rocks which contain *no animal remains* are always found *beneath*, *never resting upon*, those rocks which *do contain animal remains*: and also that those deposites which are termed *alluvial*, as gravel, sand, &c. are never found *beneath* other rocks, but always *resting upon* them.

Thus much it seems necessary to premise of geological fact, previously to entering on a detail of the

extraordinary circumstances which I shall adduce to prove the truth of our first position.

An investigation of the country surrounding Paris to a considerable extent, which by comparison may be termed low and level, has lately been accomplished by the eminent naturalist, Cuvier, associated with the acute geologist Brongniart, and they have published a masterly delineation of the geological structure of the country.

Now as chalk makes its appearance on the edge of this district, and almost surrounds Paris, though at a considerable distance from it; and as the surrounding chalk is found to dip beneath the soil, or alluvial matter within the district, and has in many places and at various depths been discovered far beneath its surface, by the sinking of wells and pits; it is justly concluded that the soil on which Paris stands, and the surrounding country, to a great extent, was actually deposited in a large hollow consisting of chalk, which therefore has been termed by Cuvier and Brongniart the *chalk basin of Paris.*

Immediately covering the chalk is found a small stratum of plastic clay, used in the manufacture of different kinds of pottery. On the plastic clay rests a deposite by *salt water*, thence termed a *marine formation:** above this rests a deposite by *fresh water*, thence termed

* The term *formation* is not always used to express a deposite consisting only of a single stratum or bed; it is also commonly used to designate a number or series of beds or strata, which being intimately associated, and containing the same description of organic remains, are thence, as well as from a variety of other circumstances obvious to the experienced geologist, considered to be of *contemporaneous formation.*

a *fresh water formation:* next above is found a second *marine formation:* above it, a second *fresh water formation;* and upon this rests an *alluvial deposite.* I now proceed to a more particular description of the nature of these five deposites.

1st *deposite.*—On the plastic clay, covering the bottom of the *chalk basin*, it has been said that the *lower marine formation* rests. This formation consists of coarse limestone abounding in marine petrifactions: associated with it, is a series of strata in regular order, as marl, sandstone, &c. all of which enclose marine shells, many of them still retaining their pearly lustre. Occasionally the space usually occupied by the limestone and the series of other strata, is entirely filled with siliceous limestone without shells, resting on the plastic clay and supporting the deposite about to be described.

2d *deposite.*—Upon the *lower marine formation* rests a deposite by *fresh water.* It consists of gypsum covered by a bed of white friable marl, enclosing petrified wood of the palm kind, and the remains of fishes and shells: the gypsum contains remains of *extinct* quadrupeds, birds, amphibious animals, fishes and shells, all of which are of *land or fresh water species.* This deposite is therefore called the *lower fresh water formation.*

In the *Gypsum*, Cuvier discovered the bones of 5 varieties of an extinct animal, which he calls the *palæotherium*, (signifying ancient large animal), varying in size from a sheep to a horse; and the bones of 5 varieties of another extinct animal, which he calls the *anoplotherium*, (signifying beast without weapons; it had no canine teeth), varying in size from the horse to the ass. Both

these species he considers to have been natives of the country over which Paris is now built.

He also found the bones of an unknown species of the *dog*, and of the *fox;* also of an *ichneumon* double the size of the living species. Nearly an entire skeleton of a quadruped of the genus *didelphis* was also found, but not belonging to any of the existing species, which are natives of America.

The fossil bones of birds are not so readily known as those of other animals; but Cuvier describes some, found along with the bones of the extinct animals, as belonging to the pelican, the starling, and the quail tribes.

Among amphibious animals, the bones of the tortoise and the crocodile are recognized.

Of fossil fish, there are 5 varieties, most of them are allied to the present species of fresh water fish.

The shells all belong to fresh water fish.

3d. *deposite*—Above the beds of gypsum and marl, just described as containing the remains *of fresh water animals*, lie two beds of oyster-shells, separated by a bed of sand and sandstone, *without shells*, from a bed of sand and sandstone, containing *marine shells*. These seem to have formed but one deposite *by salt water:*

The two beds of oyster-shells are separated by a thin bed of white marl. The shells of the lower bed are numerous, thin, small, and brown. The upper bed of oyster-shells is very thick, and the shells are arranged as they are found in the ocean: the greater number of them are whole, and have both valves.

On the bed of sand and sandstone above described, rests a bed of clayey sand and marl, in which lies the *buhrstone* or *millstone*. As it contains neither vegetable nor animal remains, it seems not sufficiently characterized to be referred deci-

dedly either to the preceding, which is a *marine* formation, or to the succeeding deposite, which is a *fresh water* formation.

4th *deposite*.—Above the buhrstone or millstone, lies a deposite of limestone and of siliceous substances, as flint, pitchstone, and jasper. The siliceous matter is sometimes allied in character to the millstone. But the essential character of the whole of the deposite is, that it contains *fresh water* and *land-shells*, nearly all of which belong to the genera now living in morasses. This formation extends 30 leagues to the south of Paris.

5th *deposite*.—Above the four deposites just described, as being alternately from fresh and salt water, lies the *alluvial* deposite, which appears to be by fresh water, and is composed of variously coloured sand, marl, and clay. It contains rolled stones of various kinds, but is most remarkable for its enclosing the remains of large organic bodies: in it are found great trunks of trees, bones of elephants, of oxen, rein-deer, and other large land animals.

This account of the contents of the *Paris chalk basin* contains important geological information. The space to which this investigation was limited, is indeed small when compared with the surface of a globe of 25,000 miles in circumference, one-third of which is of land. And if the investigation of so small a comparative spot, should not be deemed conclusive in regard to the probable nature of low and level countries in general, we have only to refer to the natural history of other parts of France and of other countries; of Germany, and of many tracts in the north of Europe, to be convinced,

than at least in degree, the same effects have been almost universal.

But it was no longer ago than in the last year, that a geological investigation of certain districts in our country,* gave an evidence, in most points, perfectly coinciding with the observations of Cuvier, in regard to the chalk basin of Paris. The minutiæ of this investigation were detailed in a very interesting communication to the Geological Society, since published in the 2d volume of its Transactions. At present we cannot do more than notice its results.

It appears that in this country there are two chalk basins, in a greater or lesser degree resembling that of Paris. One of them is called the *Isle of Wight basin;* the other, the *London basin.*

The *Isle of Wight basin* comprehends the district between Newport in that island on the south, Southampton on the north, Brighton on the east, and Dorchester on the west. The strata which cover the chalk in this district, are individually and collectively of various thicknesses; occasionally only two or three of them are found, and sometimes only one of them; but there is one place on the southern edge of this basin, which proves beyond a doubt that the same causes which operated in the Paris basin, extended their influence to the Isle of Wight, and probably at the same period of time.

The place to which I allude is Headen Hill, forming a part of Alum Bay, near the western angle of the Isle of Wight. Of this hill, which is about 300 feet high, a natural section has been laid open, since its deposition,

* By T. Webster, M.G.S.

doubtless by the sea which borders it. Any one may therefore easily satisfy himself that it contains the same description of strata as have been found in the Paris basin, and precisely in the same order; that is to say, *alternate salt and fresh water deposites*, enclosing shells, perfectly similar to those found in the Paris basin. Of the truth of this we have evidence. It is ascertained by a comparison of the shells taken from the corresponding deposites in both basins: and the animal remains so compared, are now deposited in the collection of the Geological Society in London.

The London basin begins at Deal in Kent, and extends (not in a right line) by Canterbury to Gravesend; comprehending the whole of Kent north of that line, except the Isle of Thanet, which is of chalk. The edge of the basin from Gravesend crosses the Thames at Grays, extends to Purfleet, whence it crosses the Thames again, and passes nearly in a strait line to Guildford, and from Guildford to a little west of Hungerford in Berkshire, whence it turns nearly north-east, to Maidenhead, Eaton, Watford, Hertford, Stansted, and Thaxted; but its precise extent to the north of that place is not ascertained. In a word however, the chalk basin in which London is situated, is comprehended in an acute triangle, one of its longest sides extending from Hungerford somewhat to the north of Harwich, the other from Hungerford to Deal; its shorter side taking in the whole coast from the north of Harwich to Deal, with the exception of the Isle of Thanet.

A perfect coincidence of the London with the Paris and Isle of Wight basins, in regard to the alternate depositions by salt and fresh water, does not exist, because these deposites do not alternate in the London basin.

The stiff blue clay which prevails to so great a depth almost every where round and beneath London, is *unquestionably a marine deposite*, as all its numerous animal remains, are those of *sea animals.* This clay lies immediately under the fine bed of gravel on which London is built. The wells in London pass through this clay from 200 to 300 feet; at Tottenham about 130; at Lord Spencer's at Wimbledon, 430 feet; at Harrow on the Hill, 70 feet; at Primrose Hill near Hampstead, 500 feet without success; and, except in the latter instance, all arrived at the same bed of white sand, from which the water rose.

By a paper lately read before the Royal Society, we find that at Brentford they lately passed 200 feet through the stiff blue London clay, without arriving either at water or chalk: above the clay lies a stratum of sand, gravel, and water; over that another, of 1 to 9 feet of loam; then 7 feet of sandy gravel; and then above, 9 feet of loam. These strata, *lying over the clay*, contain a vast collection of the bones of elephants, both African and Indian, of the hippopotamus, the horns and jaws of oxen, the horns of deer, and both land and fresh water shells. These circumstances clearly prove these deposites to have resulted from *fresh water*, and constitute that species of deposite which is termed *Alluvium*; whereas the *clay on which it rests*, contains only the remains of *sea animals.* The *alluvium* therefore commonly rests, in the London basin, upon the great bed of *clay*, but there exist slight traces in some places, of a *deposite by fresh water, between the clay and the alluvium.*

The clay of the London basin corresponds with the lower marine formation of the Paris basin, but the traces of a freshwater formation occasionally existing between

the clay and the alluvium, are not sufficient to decide its agreement with the lower freshwater formation of the Paris basin. Their analogy of the two basins terminates with the clay; because the alternating deposites by salt and fresh water in the Paris basin, are wanting in that of London.

In the strata above, as well as in those below the chalk, in the north-eastern parts of England, there is a remarkable agreement in point of position, in several places; in some, one or more of the strata may be wanting, *but the order in which they lie seems never to be inverted.*

If however we would take a wider range for proofs of the *more general* existence of these catastrophes that have befallen the surface of the globe, we shall easily find conviction. We are speaking now only of those to which the *lower and most level* parts of the earth have been subjected.

The bones of a species of *rhinoceros*, different from either of the three species of Africa, Asia, and the Isle of Sumatra, have been dug out of the alluvial soil near Canterbury; and since, in many places of Germany, France and Italy. In Siberia, not only single bones and skulls, but the whole animal with flesh and skin has been discovered.

In the alluvial soil of France and Italy, have been found the bones of an *hippopotamus*, allied to the two only species now known, inhabitants of Africa and Sumatra; as well as the bones of another animal not allied to these, and entirely different from any of the existing species of quadrupeds.

The *tapir* is an animal peculiar to South America, yet two fossil species have been found in Europe; the one

small, the other gigantic: both have occurred in different parts of France, Germany and Italy.

Of the *elephant*, the only existing species are those of Africa and Asia. One fossil species has been discovered, differing from each, but most nearly allied to the Asiatic. It is the *mammoth* of the Russians. The bones of the mammoth have been found in the alluvial soil near London, Northampton, Gloucester, Harwich, Norwich, in Salisbury plain, and in other places in England; they also occur in the north of Ireland; and in Sweden, Iceland, Russia, Poland, Germany, France, Holland, and Hungary, the bones and teeth have been met with in abundance. Its teeth have also been found in North and South America, and abundantly in Asiatic Russia. Pallas says, that from the Don to the Tchutskoiness, there is scarcely a river that does not afford the remains of the mammoth, and that they are frequently imbedded in *alluvial soil, containing marine productions;* the skeletons are seldom complete, still more seldom is the fleshy part of the animal preserved: but an interesting instance of this has been described.*

* The following account of the singular discovery of the carcase of a mammoth is given by Professor Cuvier, as taken from a report in the supplement to the Journal du Nord, No. 80, by M. Adams, Adjunct member of the Academy of St. Petersburg.

'In the year 1799, a Tungusian fisherman observed a strange shapeless mass projecting from an ice-bank, near the mouth of a river in the north of Siberia, the nature of which he did not understand, and which was so high in the bank as to be beyond his reach. He next year observed the same object, which was then rather more disengaged from among the ice, but was still unable to conceive what it was. Towards the end of the following summer, 1801, he could distinctly see that it was the frozen carcase of an enormous animal, the entire flank of which and one of its

Five species of an animal more nearly allied to the elephant than to any other living species, have also been discovered: it has been called the *mastodon*. The five species are all herbivorous, the largest is about the size of the elephant; but no living species of the mastodon has been discovered in any part of the world: the fossil remains were found in Europe and America.

All these fossil species of quadrupeds have occurred in *alluvial soil that covers the bottoms of vallies, or is spread over the surface of plains;* none have been found in high vallies: the bones of some were covered by *marine shells* and remains, others by *fresh water shells;* and as no remains of these animals have been seen in any solid rock, or in any high mountain, it seems pro-

tusks had become disengaged from the ice. In consequence of the ice beginning to melt earlier and to a greater degree than usual in 1803, the fifth year of this discovery, the enormous carcase became entirely disengaged, and fell down from the ice-crag on a sand-bank forming part of the coast of the Arctic Ocean. In the month of March of that year, the Tungusian carried away the two tusks, which he sold for the value of fifty rubles; and at this time a drawing was made of the animal, of which I possess a copy.

'Two years afterwards, or in 1806, Mr. Adams went to examine this animal, which still remained on the sand-bank where it had fallen from the ice, but its body was then greatly mutilated. The *Jukuts* of the neighbourhood had taken away considerable quantities of its flesh to feed their dogs; and the wild animals, particularly the white bears, had also feasted on the carcase; yet the skeleton remained quite entire, except that one of the fore-legs was gone. The entire spine, the pelvis, one shoulder-blade, and three legs, were still held together by their ligaments and by some remains of the skin; and the other shoulder-blade was found at a short distance. The head remained, covered by the dried skin; and the pupil of the eye was still distinguishable. The

bable that these animals fell victims to some of the latest catastrophes that have befallen the globe; and though some of them differ from their co-species now existing in the torrid zone, there seems reason for supposing them to have been inhabitants of the regions in which their bones are found. The mammoth found whole in Siberia was too warmly clad for the torrid zone.

Additional proofs of the *extensiveness of these catastrophes*, both by salt and fresh water, may be found in the famous rock of Gibraltar, and at various places on the coast of the Mediterranean.

The rock of Gibraltar is principally limestone, and is traversed by fissures or hollowed into caves, which con-

brain also remained within the skull, but a good deal shrunk and dried up; and one of the ears was in excellent preservation, still retaining a tuft of strong bristly hair. The upper-lip was a good deal eaten away, and the under-lip was entirely gone, so that the teeth were distinctly seen. The animal was a male, and had a long mane on its neck.

'The skin was extremely thick and heavy, and as much of it remained as required the exertion of ten men to carry away, which they did with considerable difficulty. More than thirty pounds weight of the hair and bristles of this animal were gathered from the wet sand-bank, having been trampled into the mud by the white bears, while devouring the carcase. Some of the hair was presented to our Museum of Natural History by M. Targe, censor in the Lyceum of Charlemagne. It consists of three distinct kinds. One of these is stiff black bristles, a foot or more in length; another is thinner bristles, or coarse flexible hair, of a reddish-brown colour; and the third is a coarse reddish-brown wool, which grew among the roots of the hair. These afford an undeniable proof that this animal had belonged to a race of elephants inhabiting a cold region, with which we are now unacquainted, and by no means fitted to dwell in the torrid zone. It is also evident that this enormous animal must have been frozen up by the ice at the moment of its death.

tain a peculiar compound mass, consisting of angular fragments of limestone, of bones, usually of ruminating animals, generally broken, never in skeletons; and of land shells, cemented together by a calcareous basis: the bones were for a long time thought to be those of monkies, but Cuvier has with his peculiar sagacity, considered some of them to belong to a species of antelope, others to a kind of mouse.

At *Cette*, the limestone includes bones like those of a rabbit; others similar to those of the field mouse, and of a bird of the sparrow tribe; the vetebræ of a serpent, together with the bones of some ruminating animal, and three various kinds of land shells.

At *Nice* and the *Antibes*, the rock also contained the bones of the horse.

In *Corsica*, the rock contains the bones of small quadrupeds, chiefly foreign to the place; as those of one inhabiting the coldest and wildest parts of Siberia; and enormous quantities of bones, some of which resemble those of the field mouse, and others those of the water rat.

In *Dalmatia*, the bones contained in the rock are principally like those of Gibraltar.

At *Concud* in Arragon, the rock contains the bones of the ox, ass, a small kind of sheep, and many land and fresh water shells.

We have now, as it seems to me, satisfactorily illustrated our first position to a considerable extent, viz. 'That the lowest and most level parts of the earth, consist of horizontal strata, composed of various substances, many of which contain marine productions.'

LECTURE IV.

Organic Remains visible in hills and on the sides of elevated mountains—Strata of the Brocken mountain—Summits of lofty mountains contain no organic remains—Heights of mountains—Division of rocks into primitive, transition and flœtz (or secondary) and alluvial—their definitions.

On the last evening, the real objects of Geological inquiry were pointed out. It was shewn that these consist of the *natural phenomena and facts* every where discoverable; and that without an ample and nice investigation of these, it is impossible for us ever to attain a reasonable knowledge of the earth: such a knowledge, I would say, as may be derived from some acquaintance with the component masses of its crust, and of their relative positions. It was also shewn how unsatisfactory and absurd are the speculations of mere closet-philosophers; who, relying on their inventive powers, and on the extreme difficulty of contradicting their theories, indulged themselves in speculations scarcely less ridiculous than it would be to assert that the globe is an egg or an oyster.

During the last evening also, were laid down a series of *geological positions*, as they may be termed, which have been found to result from the truly philosophical labours of men who have investigated the crust of the globe, perhaps to as great a height and to as great a depth, above and beneath the surface of the sea, as man can easily attain. These geological positions I proposed

to illustrate by quoting the experience of the very men from whose labours they have resulted. The first of them, viz. 'That the *lowest* and *most level* parts of the earth, when penetrated to a great depth, exhibit nothing but *horizontal* strata, composed of various substances, and containing almost all of them innumerable marine productions,' was then elucidated by the investigation of the chalk basins of Paris, of London, and of the Isle of Wight: and not only the truth of the foregoing position was made clearly to appear, but also the novel and interesting facts, that in these basins there have been successive and alternate deposites from *salt* and *fresh* water; which is proved by the nature of their strata, and the organic remains they respectively contain. And it was further shewn that these catastrophes so fatal to animal life, have not been partial; inasmuch as they are readily and largely seen in almost every part of the European continent, and particularly on the coasts of the Mediterranean sea.

The object of our present inquiry into the nature of the constituent masses of the surface of the globe, is so extensive as not to admit of those immediate convictions of the truth of what may be asserted respecting them, as might be desirable. I claim however this advantage; I demand no assent to theory, for I will not broach a theory. I offer alone the results of inquiries among the *facts and phenomena of nature*, by men whose love of nature and of truth, has rendered their researches invaluable to science: researches amid regions always open to the investigations of the doubting or disbelieving. Amongst these men, let us remember that we have an Humboldt, a Werner, a Saussure, and a Cuvier. What but the love of truth and of science could have induced

Humboldt to traverse whole continents, or to ascend the Andes more than 18,000 feet above the level of the sea; or Werner, the great German geologist, to employ his life in examining the rude and mountainous regions which surround him, and in teaching the results of his inquiries? What but the love of truth and of science could have led Saussure to investigate every corner of the Alps, during twenty years; or have induced Cuvier to bestow twenty-five years of his life in the study of comparative anatomy and osteology, with a view principally, if not solely, to the illustration of the nature of our globe?

If from all that Humboldt, and Werner, and Saussure, and Cuvier, and many other intelligent geologists, have observed in regard to the nature and respective positions of the great masses forming the crust of the earth, we were to select such parts as would immediately come in evidence of the truth of the geological positions already submitted to your notice, scarcely fifty evenings would afford time sufficient for their recital. It is my object to bring the required evidence into the narrowest compass; I shall therefore select only such as may suffice to attain our object; taking care, at the same time, that it shall be of the most obvious kind that the nature of our inquiry will permit.

The positions already recited begin with the *lowest and most level* parts of the earth; these we have considered. We now ascend a little, that is to say, to the *hills*; and after a short notice of their nature, shall rise to the consideration of the masses constituting *lofty mountains*; taking occasion, here, to present an outline of the divisions which the experience of geologists has taught them to make in rocks, as the component masses

of the crust of the globe; shewing the reasons for their division into primitive, transition and flœtz, (or secondary) and alluvial; and that of each of these there are many varieties.

The 2d position is, That strata containing shells are found in hills to a great height.

3d. That the shells are sometimes so numerous as to constitute entire strata.

4th. That shells are found in elevations *far above the level of the sea*, and at heights to which the sea could not be raised by any existing cause.

5th. That these shells once lived in the sea and were deposited by it.

6th. That shells continue to be found as we rise to the foot of great chains of mountains.

These positions I purpose to consider together. The evidence of facts requisite for their support, and as proofs of their truth, need not detain us long.

The cliffs of the Isle of Sheppey, bordering our own river the Thames, do not rise to any considerable height above the level of the water. They have however long been celebrated for the numerous organic remains found in them, a list of which was published several years ago. This list has since been enriched by a gentleman now resident at Faversham, by the addition of above 700 different species of fossil fruits, berries, and ligneous seed vessels. Among the animal remains found in these cliffs, are several varieties of the crab, the jaws of crocodiles, and lobsters nearly whole. It deserves notice that all these remains, both vegetable and animal, are entirely impregnated with sulphuret of iron, or pyrites.

At Reading in Berkshire, or rather in the elevated

lands in its neighbourhood, are found considerable deposites of oyster shells; it is remarkable that many of them are entire, having both their valves united, but the animal matter, or oyster, is entirely decayed. These shells have not undergone the process of petrifaction; they are white, extremely brittle, and readily separate into laminæ. In Touraine in France, 100 miles from the sea, and about 9 feet under the surface, there is a bed of shells 9 leagues long and about 20 feet thick. According to Ulloa, there are similar deposites in Peru. Such are likewise well known to exist in almost every part of Europe. In the neighbourhood of Bath, at a rather higher elevation, large tracts of limestone are found, consisting almost wholly of shells; which are also discoverable in great abundance in the Gloucestershire hills, and in other parts of England. In the cliffs near Whitby, a crocodile has been found; in those near Lyme in Dorsetshire, their remains occur in considerable abundance; and in the chalk cliffs of Dover, some varieties of fossil shells. Still higher, in various parts of Germany the fossil remains of fish are found in hills and rocks of various kinds of slate.

Let us however continue to ascend. Dolomieu found immense quantities of sea shells on the sides of Mount Ætna, 2000 feet above the level of the sea; and at the height of 2400 feet above the same level, he found in the mountain itself, regular strata of grey clay enclosing sea shells.

Some of the lower hills of the Appennine chain contain many species of shells; they contain also the fossil bones of elephants, of the rhinoceros, of the hippopotamus, of whales and of dolphins.

It is asserted by Cuvier, in regard to the shells which

are found imbedded in some rocks, that 'A nice and scrupulous comparison of their forms, of their contexture, and even of their composition, cannot detect the slightest difference between some of these shells, and the shells which still inhabit the sea;' an assertion which perhaps no one who has at all examined it, will presume to deny. Surely then we have a right to assume that they once lived in the sea, and that they were deposited by it; and if deposited by it, that the sea must have been once sufficiently elevated; since we know of no other cause adequate to the deposition of rocks enclosing sea shells, and to their deposition in regular strata. And when we take into consideration that Mont Perdu, which is the highest of the Appennines, and reaches an elevation of 11,000 feet above the level of the sea, encloses so immense a quantity of sea shells, as that some of its strata seem almost wholly composed of them; we shall at once assent to the position that shells are found in places to which the sea could not be conveyed by any existing cause.

Mont Perdu is by no means the only elevated mountain enclosing sea shells; it is however one of the highest; and we may readily infer that if a mountain of so great elevation encloses them, they will be found in the strata at the foot of great chains of mountains.

According to Saussure, the Buet, a mountain which rises 10,000 feet above the level of the sea, contains no petrifactions; but the Salenche, the Mole, and others not exceeding 7000 feet, are found to enclose petrifactions, although they form a part of the same chain.

The Altaic chain of primitive mountains in Siberia encloses no animal remains; but it is flanked on each side by a chain of hills which enclose marine shells.

The 7th position is, That at the foot of lofty mountains, the strata, instead of being horizontal as in plains and low hills, are of *various degrees of inclination*, and sometimes *vertical*.

8th. That from these and other circumstances, it is inferred that there have been successive irruptions and retreats of the sea.

9th. That as we approach the *summits of lofty mountains*, their strata become wholly different;—the remains of marine animals and shells become rare, and even disappear altogether.

10th. That their strata are, by some, considered not to be precisely in the position in which they were formed.

11th. That, as they contain no vestige of animal remains, they are considered to be the oldest rocks, and therefore are called *primitive*.

In proof that the *strata*, as we approach the foot of lofty mountains, are not horizontal as in low hills, I shall present to your notice the section of a mountain in the Hartz Forest in Germany, made from the description given by Werner himself. This mountain is called the Brocken, (see plate 3.) and rises to a considerable elevation, though it is not one of the highest mountains in Europe: but the result of the examination of its surrounding strata by Werner, is better evidence of the facts it discloses than we could perhaps obtain from any other source. The center is of granite, which is, as it were, mantled all around by several successive and perfectly distinct strata; the oldest next to the primitive rock, and invariably, each succeeding stratum, being newer than the preceding, dips lower and lower, as we

depart from the primitive rock around which they are successively deposited. The nature of the several component masses of this mountain, will be further noticed when we arrive at the consideration of the mineralogical differences existing in mountain rocks.

The successive deposition of these strata (for that they were successive will become more apparent when their geological differences shall have been pointed out) may at least in degree be urged in proof that there have been repeated irruptions and retreats of the sea: they will moreover evince that *the sea has not always deposited stony substances of the same kind*, inasmuch as these deposites are distinct, and even essentially different, in their natures: and the strata surrounding this mountain may be brought in evidence, perfectly in agreement with numerous other observations, that the sea *has observed a regular succession as to the nature of its deposites.*

And from these circumstances, it is reasonable to infer that the *sea has undergone great changes in the nature of its fluid:* whence we may presume that there may have been *a succession of changes in the nature of the animals which inhabit it*, corresponding with the changes in the chemical nature of the sea.

That such changes have taken place in the nature of the inhabitants of the sea, we have abundant proof.

Not only do *the species and even genera of the shells change with the strata*, but it is generally the case that *the shells of ancient strata have forms peculiar to themselves;* that these forms gradually disappear; that they are not found in the strata *recently deposited*, nor in the *existing* seas: but the more *recent strata* enclose some species which the most experienced eye cannot distinguish from those *which now inhabit the ocean.*

The section of the Brocken mountain shows the reason for our assertion that, as we approach the summits of lofty mountains, the remains of marine animals and shells become rare, and even wholly disappear. It has already been stated that granite, which forms the center and summit of this mountain, is considered to be the oldest of rocks, because it is found underneath all others and frequently rises through and overtops all other the constituent masses of mountains, as well as because it never contains animal remains ; granite, in like manner, constitutes the highest parts of very many mountains of different elevations throughout the globe. But it is often found that, although in some countries the sides of very lofty mountains have been covered by succeeding strata to a very great height; yet in other countries, primitive granite of very inferior elevation is exposed almost to the level of the sea, without having any part of it covered by secondary deposition ; and the fact seems to be that these secondary depositions have greatly varied in extent, in character, and in elevation.

We now come to the consideration of the summits of lofty mountains which contain no vestige of a living creature, and whose stratification, if it may be so called, differs from that of mountains of less elevation.

The summits of lofty mountains generally consist of one or two, and sometimes of alternating, deposites of some of the older rocks; which for the reasons already given have been termed *primitive*. Some of these rocks mostly assume one appearance; others have mostly an appearance wholly different: I say mostly, because there are but few rocks that always assume the same appearance in regard to stratification.

For instance, granite and some other of the older rocks, sometimes occur in regular and nearly horizontal strata; sometimes have no appearance of regular deposition, either horizontal or inclined; but the summits of lofty mountains, constituted of such rocks, seem composed of large and irregularly sized blocks, piled on each other without any appearance of order: while on the contrary, *gneiss*, another primitive rock, is almost invariably in strata, either horizontal or inclined.

This diversity in appearance is very considerably augmented in mountains consisting of alternate masses of primitive compounds, which are by no means rare; and as these rocks suffer in different degrees by long exposure to the action of the elements, this circumstance considerably contributes to increase the disorder of their rugged summits, which are described as appearing at a distance like the ruins of towers and of fortifications.

Whether these constituent masses are still in their original position is a problem of no inconsiderable interest; nor can we wonder that able geologists should differ on the subject. Cuvier on the one hand, considers that the very appearances of their summits, are so many proofs of *the violent manner in which they have been elevated.* He is of opinion that all the older strata of which the crust of the earth is composed, were originally in a horizontal position; and that they have been raised into their present highly inclined position, by subsidences that have taken place over the whole earth.

On the other hand, Jameson, (who is a rigid follower of the opinions of Werner, whence we may infer that it is also Werner's opinion,) believes that the present inclined position of these strata is, in general, their

original position; an opinion which he considers to be countenanced by the known connection of strata, the phenomena of veins, the crystalline nature of the older rocks, and also by what he terms the great regularity in the direction of strata throughout the globe.

Since, therefore, two authorities so eminent have not yet decided the point, and since their opinions are directly opposed to each other, we must be content to await and to expect an agreement, drawn from yet further inquiries amid the phenomena presented by the grand features of mountain rocks.

But the researches and experience of many skilful geologists, all unite in this: *that the strata composing the summits of lofty mountains contain no vestige of animal or organic remains;* they *are therefore considered to be in their primitive state.* An approach towards these summits discovers that the sides are covered, or, like the Brocken mountain, mantled around to a very great elevation, by deposites enclosing sea shells and other organic remains. These are common in the lower Pyrennees, whose elevation does not exceed six or seven thousand feet above the sea: according to Ulloa, however, shells have been found at the height of 14,220 feet above the sea on a mountain in Peru.

It is extremely difficult, it is even in most cases impossible, to ascertain the internal structure of large and elevated mountains: but if on ascending them, it be found that their summits are crowned by certain rocks which are *known never to include shells or other organic remains, and which have never yet been found resting upon those rocks which do contain them;* we have a right to conclude, from analogy, that the same rock which forms the summit, composes the mountain

itself, ascending from the base to the summit through the center; and that the masses of rock surrounding it, even to a great elevation, were deposited after the creation of the central mountain.

We may, I say, conclude this to be the case from analogy, because in certain districts of the European continent, the operations of the miner have occasionally disclosed the fact. In various parts of Germany some mines are situated in lofty mountains. For instance, in the Krivan mountain, there is a gold mine, 6954 feet above the sea; and in the mountains of the Tyrol, a silver mine, 7512 French feet above the same level.

As we are now upon the subject of mountains, it may not be amiss here to introduce a sketch exhibiting the comparative heights of some in various quarters of the globe, whose names are best known to us, as most frequently occurring in the usual course of our reading: it is not intended to convey a representation of their actual form (see Plate 1). To us, who live in a low and almost level country, Skiddaw and Helvellyn are objects of wonder and admiration; but when these, or Ben Nevis, which is the highest mountain in Britain, are compared with the majestic elevations of the European or the American Continents, they sink in our estimation into mere hillocks; and the great pyramid of Egypt, that wonder of ages, which is 315 feet in height, seems as nothing in point of bulk. The heights of two or three remarkable cities have been added.

The highest mountain in Europe is Mont Blanc in Switzerland, which is 15,662 feet above the sea; but there are several of nearly the same height.

The highest mountain in Asia is Petcha, or Hamar, in Chinese Tartary, which is estimated at 15,000 feet above the plains of China; unless it be admitted that the highest summit of the mountains of Thibet exceed it, which, according to Colonel Crauford, is about 25,000 above the sea.

In Africa, the highest mountains are supposed to be those of Geesh, which are estimated at 15,050 feet above the sea.

Chimborazo, the highest summit of the Andes, and the most elevated of the American continent, is 20,282 feet above the sea; but there are fourteen other mountains on that continent, between 10,000 and 20,000 feet in elevation; several of which are volcanoes.

Heights of Mountains, &c.

		feet above the sea.
Britain . .	Ingleborough, Yorkshire . .	3000 ?
	Ben Lomond, Scotland . . .	3048
	Saddleback, Westmoreland . .	3240
	Helvellyn, Cumberland . . .	3324
	Snowdon, Wales	3456
	Skiddaw, Cumberland	3530
	Schihallien, Scotland	3564
	Ben Nevis, Scotland	4350
Italy . .	Vesuvius	3900
France . .	Puy de Dome	5000
	Puy de Lanff	6200
	Plomb de Cantal	6300
Jamaica .	Blue Mountains	7431
Germany .	Lomnitz Peak	8640
	Kesmark Peak	8508
	Krivan	8300
Pyrennees .	Canigou	9000
	Mont Perdu	11,000

		feet above the sea.
Canary Islands	Peak of Teneriffe	11,424
Sicily . .	Ætna	10,032
Alps . .	Lake Lauzon. Mont Olan . . .	6796
	Mont Titlis	10,818
	Schrekhorne	13,000
	Mont Rosa	15,000
	Mont Blanc	15,662
America .	City of Mexico	7424
	City of Quito	9000
	Silver Mine of Jauricocha . .	15,500
	Tunguragao	16,170
	Cotopaxi	18,600
	Chimborazo	20,282

We have now arrived at that branch of our subject which may be termed *Mineral Geology* ; *which has for its object the natures and differences existing in the component masses of the earth.*

These masses are, by Werner, divided into *primitive*, *transition*, *flœtz*, and *alluvial*.

Primitive Rocks *never contain animal or other organic remains*, and are never found to alternate with, or to rest upon those rocks, which enclose animal remains.

Primitive rocks are so named, because, in so far as we know, they are the oldest, and were the first formed. They have a crystalline appearance, and are therefore *chemical deposites*, principally composed of the *siliceous* and *argillaceous earths*.* Granite, gneiss, mica-slate, clay-slate, primitive limestone, serpentine, porphyry

* The earth called *alumine* forms the basis of common alum, whence it obtained that name ; it enters largely into the composition of clays, whence it is termed the *argillaceous earth*, from the Latin *argilla*, clay.

and sienite are of this kind. Of these, granite is considered to be the oldest, and sienite the newest.

To primitive rocks succeeds another class, which Werner denominates TRANSITION ROCKS; these *enclose organic remains of animals not now inhabiting the seas*, and are principally composed of *chemical deposites*; but amongst them *mechanical deposites* first make their appearance.†

Limestone, though it sometimes occurs among primitive rocks, first appears in considerable quantity among transition rocks; amongst which greywacké, greywacké-slate and transition limestone are the predominating rocks.

Still newer than transition rocks, is the extensive class of FLŒTZ ROCKS; the *older* of these contain the

† The difference between a chemical and a mechanical deposite may be thus explained.

A *chemical deposite* is the result of that law of nature which has been already explained, called *affinity*.

Pounded flint, which is nearly pure silex, with a certain proportion of potash and of some other substances, when melted, forms a glass which is soluble in water. When thus dissolved, the mixture is called the *liquor of flints*. It is said that a quantity of this liquor was left in a bottle during eight years by Professor Siegling; who found that the force of affinity acting upon the particles of silex in the liquor, caused them to be deposited in transparent crystals of quartz, hard enough to give fire with the steel. These crystals were therefore a real *chemical deposite*.

A *mechanical deposite* is effected without the agency of affinity. If for instance sand or clay be mixed up in water, it will be deposited without regularity, or intimate combination, merely by its own weight. If this deposite be left to dry, and to become hard, it will not break in any particular direction, nor will the particles of which it is composed adhere together very strongly. There is no regularity, it is a mere accidental or *mechanical deposite*.

remains of sea fish *approaching in character to the kinds found in the ocean*, and the *newer* of them contain *shells precisely the same as now exist in the sea.* Flœtz rocks are for the most part, *mechanical deposites.* The principal among these are limestone and sandstone; to which may be added gypsum, salt, and great accumulation of inflammable matter in the state of coal.

Still newer is the class of ALLUVIAL ROCKS; these contain the *shells of fish now existing in the seas, and the bones of large land animals;* and are almost entirely composed of *mechanical deposites.* Sand, clay, loam and brown coal are the principal earthy masses that belong to this class.

Such are the divisions which observation has taught the experienced Werner to make in rocks. Some other geologists however are of opinion that the division made by him of rocks enclosing organic remains into two classes, transition and flœtz, is unnecessary: they therefore term *all those rocks which contain organic remains*, excepting those called alluvial, SECONDARY ROCKS.

We learn from what has preceded

1st. That the older rocks are principally composed of the siliceous and argillaceous* earths.†

2nd. That the primitive parts of the crust of the earth are entirely *chemical* productions; whereas, in the newer, we find a beginning, and in the still newer, an increasing quantity of *mechanical* depositions.

* See last note but one.

† See notes to the descriptions of the nine oldest and most abundant of the primitive rocks.

3d. That limestone occurs but sparingly in the primitive, more abundantly in the transition (or older secondary), and in the flœtz class (or newer secondary) in immense quantity.

4th. That in the earlier deposites we meet with no bituminous or saline matters, as coal or slate, but that these occur in great quantity in the newer formations.

But that part of our subject to which we are now arrived, viz. the consideration of the *nature of the individual rocks or compound masses*, which have been brought to light by the operations of the miner, or the researches of the geologist, opens to us a field of inquiry of such amazing extent, as to induce me to pause, and, for a moment, to consider the precise nature of the object we have in view.

This, if I rightly understand it, is the acquisition of such *knowledge of the great outline of geological facts and phenomena*, as the researches of men eminent in science have enabled us to attain; avoiding on the one hand an attempt to enter with mineralogical exactness into the study of every geological compound, and on the other, the bare recital of a catalogue of geological names; neither of which would afford either interest or instruction.

In the consideration of the nature of individual rocks, is involved the remainder of our geological positions. We proceed to the

12th. That rocks which, because they include no vestige of animal remains, are termed *primitive*, are of various kinds.

13th. That rocks enclosing animal remains are

never found underneath, or supporting, those rocks which are termed primitive.

14th. That some primitive rocks alternate with each other; but that granite is found beneath all others, and frequently overtops all the rest.

15th. That rocks which include organic remains must have been formed *after* the shells they contain, and *therefore*, not being considered *primitive*, they are, by some, termed *secondary rocks:* whence the terms used by geologists of *primary* and *secondary formations.*

16th. That there are many varieties of *secondary rocks*, each of which has received a geological appellation.

17th. That there exists another class of substances, not appropriately termed *rocks*, but which, being considered to be the *debris*, or ruin of rocks, by their long exposure to the action of air or water, or both, are therefore termed *alluvial deposites.*

I shall now invite your attention to that classification of rocks which the experience and observations of Werner have induced him to make.

It is however essential that we should regard the following classification as being founded on observations confined chiefly to one large and important district of the European continent; and it is also essential for us always to recollect in adverting to this classification, that some geologists are of opinion that certain other rocks ought to be added, and also that in some other parts of the continent, and in some districts of Britain, *these rocks have not always been found precisely in the fol-*

*lowing order.** I shall advert again to this subject presently.

Primitive Rocks.

Granite	*Porphyry*
Gneiss	*Sienite*
Micaceous schistus	*Topaz rock*
Argillaceous schistus	*Quartz rock*
Primitive limestone	*Primitive flinty slate*
Primitive trap	*Primitive gypsum*
Serpentine	*White stone*

Secondary Rocks;

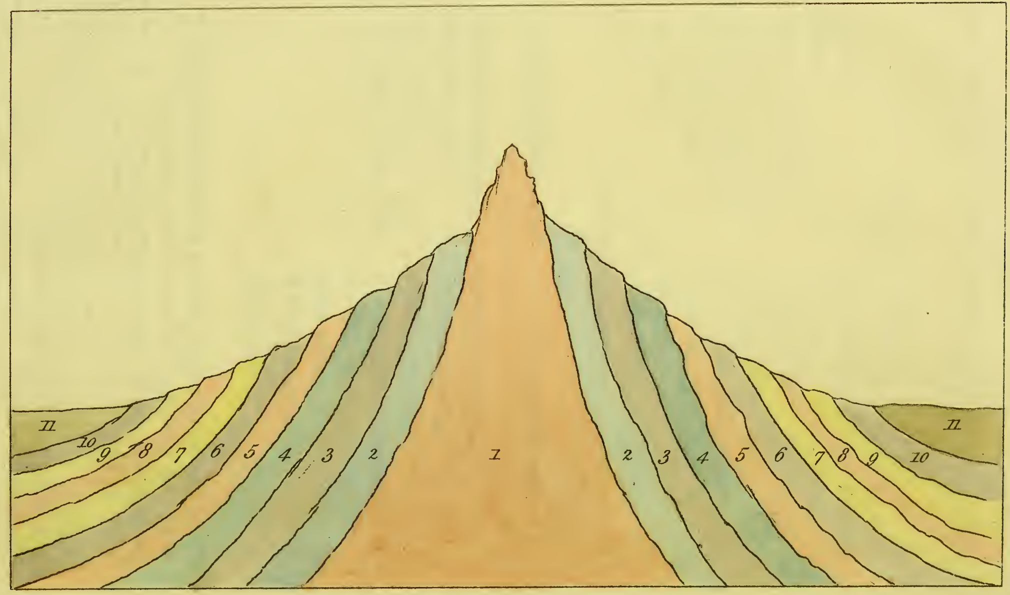
or

Transition Rocks.	Flœtz Rocks.
Transition limestone	*Old red sandstone*
Transition trap	*Flœtz limestone*
Greywacké	*Flœtz gypsum*
Transition flinty slate	*Variegated sandstone*
	Second flœtz gypsum
	Shell limestone
	Third sandstone
	Rock salt

* It would be tedious here to point out the exceptions; it will suffice to say that some may be found by consulting the several interesting and luminous communications by Dr. Mac Culloch to the Geological Society, of which he is now President: these papers are published in its Transactions.

The classification of Werner is therefore introduced here, because it is the result of the actual observation, and because it is essential to shew that order prevails. The exceptions above alluded to are not destructive of this doctrine.

Plate 3.



Section of the Brocken Mountain; Hartz Forest, Germany.

Chalk
Flœtz trap
Coal
Newest flœtz trap

ALLUVIAL DEPOSITES.

Sand, gravel, loam, clay, wood-coal, &c.

But before we proceed to examine these rocks individually, let us take some further notice of the interesting section of the Brocken Mountain, which throws much light on the subject of the relative situation of mountain masses in general. An outline of the nature of these masses will of course be comprehended in the succeeding description of individual rocks. The center of the mountain is *granite* (1), on each side reposes another primitive rock called *clay slate* (2), *which, as well as all the succeeding strata, is found entirely to surround the granite.* The two strata next in succes-cession (3, 4) are by Werner termed transition rocks; the first being *limestone*, the next *greywacké* and *greywacké-slate*. The stratum resting on the latter is called by Werner, the *old red sandstone* (5), and is the oldest of what he terms the flœtz rocks; the succeeding strata to (10) inclusive are also flœtz rocks. On the old red sandstone reposes the 1*st flœtz limestone* (6); on it the 1*st flœtz gypsum* (7); then succeeds the 2*nd* or *variegated sandstone* (8); then the 2*nd* or *newer gypsum* (9): and lastly the 2*nd limestone* (10). It is essential to be noticed that I do not pretend to give the precise extent, dimension, or shape of the granite forming the centre of this mountain, or of the several successive and incumbent strata; their general shape and position is all

that is intended to be conveyed. Nor must we forget to observe that, in reality, all the strata incumbent on the granite, are less and less in elevation as they are more and more distant from it, each newer deposite being lower than that preceding it in point of age and situation. Nor must we fail to remark that these several strata, which may be supposed to stretch along through a considerable tract of country, would soon assume that position which determined Werner to give to the newer amongst them the term of flœtz rocks; that is to say, they would be *flat*, which is the meaning of the word flœtz. On the 2d limestone (10) reposes the *alluvial deposite* (11), with the precise nature and extent of this, I am not acquainted.

This section has so greatly the appearance of order and of art, that it might be supposed to be the mere contrivance of some theorist to answer the particular objects of his invention: but we have no reason to suspect it. That Werner is in some sort a theorist, perhaps, can scarcely be denied; but it must at the same time be allowed that his great object has been to develope a grand outline of the facts presented by nature, and that his theory is wholly built upon investigations, to which the great mining and mountainous district in which he resides is particularly favourable. A Cornish miner of observation and talent, but whose education and knowledge is principally confined to his art; who had never read, or perhaps even heard of a theory of the earth, lately told me that on examining a certain district in Wales, he was surprized to find on the side of a mountain, strata of various kinds in regular succession, and much more so to observe the *same strata in the same order* on the side of another mountain distant nearly 20

miles from the former. It was the more remarkable to him, because Cornwall is not a stratified country.

I have selected for your inspection the section of the Brocken mountain, as being a well authenticated example of remarkable order in its several deposites, and because the relative position of rocks, and the order in which they succeed or cover each other, forms a curious and interesting part of geological inquiry. If however we were to imagine that this forms a representation of the deposites of mountain masses in the aggregate, we should err. Though granite frequently overtops other rocks, it is perhaps more frequently found that other primitive rocks rest immediately *upon and above* it. Granite is sometimes observed to alternate with gneiss, and gneiss with micaceous schistus and clay-slate.

Mont Blanc, which is 15,680 feet high, and is the highest mountain in Europe, is of granite nearly to the summit; which is, according to Saussure, of argillaceous schistus. It is said that in the Andes, in South America, granite has not been seen higher than 11,500 feet above the sea. A mountain called Marno, in Portugal, is granite covered by clay-slate enclosing crystals of a mineral called the chiastolite. The same rock enclosing the same substance, forms the summit of Skiddaw in Cumberland, probably resting also on granite.

It is sometimes found that several of the primitive rocks rest upon granite, and above these some of the transition or flœtz rocks: or, as they have been conjointly termed by some geologists, secondary rocks. Even alluvial matter is said to have been observed, covering the summits of elevated mountains.

But it has been objected to the rules laid down by Werner, in regard to the relative ages and positions of

rocks as forming mountain masses, that, as his observations have been chiefly confined to the country in which he resides, it is not reasonable to adopt the result of researches with regard to one district, as obtaining in every other country. This objection is in some degree well-founded. The observations of other geologists in other countries *certainly are not all* in perfect accordance with the rules laid down by Werner. This dissonance is attributable to various causes. Some actual exceptions to his classification* have been discovered; but in some instances, it is reasonable to infer, that this disagreement may be attributed in some measure to the yet imperfect state of the science, and to the want of precise definitions in regard to the characters of many rocks. Some, which have obtained the same appellations, are so different in appearance, that the most experienced eye alone can determine their general agreement in regard to character and composition; while, on the other hand, certain others have obtained different names in different countries. In this imperfect state of geological language, the knowledge and skill of the observer must always be had in consideration.

If Werner be actually a theorist, he is one of a superior order. He has extended his researches throughout the large and important district surrounding him. The relative age, deduced from the relative position, internal structure, and contents of the great masses forming that mountainous district, seems to have been ascertained by him with a degree of certainty that defies the application of the term *theory* to his results. If he merit the name of theorist at all, it seems only to be in

* See preceding note.

consequence of his assertion, or supposed assertion, (fo hitherto his principal discoveries have been communicated only by some of his pupils) that the same results will be found to prevail universally. It is certain that researches in almost every quarter of the globe, have tended in an astonishing degree to verify his opinions, that *order in regard to deposition is universally prevalent, and that this order is never inverted.*

It cannot however be denied that theories built even upon researches into the phenomena presented by nature, have both advantages and disadvantages. They serve to induce research, inquiry and discussion; which, when carried on with that temperate zeal which may be expected from men whose object is truth, will be sure to promote it. It were to be wished that the love of truth were thus prevalent; much needless and intemperate warmth would be averted; and were observers bent on this alone as their ultimate object, science would be benefited by nicer and more candid geological description than can be expected from those, whose great object is the support of a favourite theory.

Inquiries into the nature of the globe contribute greatly to the advancement of real science: they serve at once to amuse and to instruct, by affording ample materials for reflection; they force upon the mind an immoveable conviction that the globe itself was called into existence by *a power, whose design and contrivance are every where manifest*: a power, whose immensity is unsearchable.

The few rocks that have been mentioned as composing the principal masses of primitive, transition and flœtz, or secondary rocks, and of alluvial deposites, comprehend, as it were within their catalogue and con-

nected with their history, a variety of other rocks so vast and so numerous, and passing the one into the other by such imperceptible and nice gradations, that it may truly be said their study is the business of a life.

I now proceed to offer some remarks on the nature of individual rocks; beginning with the oldest of the primitive rocks, and taking occasion to notice some of their masses, remarkable for extent and elevation, as well as the metalliferous ores which principally abound in them.

Granite is a compound, granular, aggregated rock, composed of felspar, quartz and mica, mostly in distinct crystals; sometimes the one, sometimes the other of these ingredients predominates, but most generally the felspar.*

But granite varies in respect to its granular character, from the very large to the very small; the larger granular is considered to belong to the oldest formations, the small and fine grained granite to the newest.

Werner considers that there are three sorts of granite: the primitive; a newer formation which traverses other primitive rocks in veins, and the newest granite formation; this latter always rests on some of the older primitive rocks. It sometimes contains portions of other rocks.

* Quartz, felspar and mica, enter into the composition of granite and gneiss, the two oldest of the primitive rocks. Quartz is composed of silex, with 2 or 3 per cent. of moisture or water. Felspar, of abou 63 parts of silex, 17 of alumine, 3 of lime, 13 of potash and 1 of oxide of iron. Mica, of about 47 parts of silex, 20 of alumine, 13 of potash, 15 of oxide of iron, and 2 of oxide of manganese.

The colour of granite is greyish white or reddish.

Granite sometimes contains other substances, as schorl, garnets, tin ore, and molybdena: many mineral substances are found in veins that traverse it; as tin ore, rock crystal, topaz, fluate of lime, phosphate of lime, &c. It is said that in Switzerland beds of quartz, whose cavities contain magnificent rock crystals, occur in granite.

In the great mining field in Cornwall, both copper and tin occur in veins in granite in prodigious quantities.

When granite is exposed, it forms very high and steep cliffs; often also it appears as lofty and precipitous summits, denominated peaks; as is remarkably the case in Savoy in Switzerland.

It occurs, as forming mountain masses, both *unstratified and stratified;* when in the former state, it presents large irregularly shaped masses, sometimes distinct globular concretions, as in Bohemia, the Hartz, and other places. Stratified granite occurs in Bohemia, Saxony, Switzerland, the Pyrennees, the Altaic mountains, and in other countries. According to Jameson, 'Strata can only be formed by parallel seams, which have the same direction and extent throughout the mass.'

Granite is one of the most frequent and widely extended rocks: it forms the summits of the highest mountains in Scotland, in the Hartz, the Alps, in Bavaria, Bohemia, the Tyrol, and most countries in Europe. It forms a very considerable portion of the Uralian and Altaic chain of mountains in Siberia in Asia. In Africa, it forms the principal constituent part of the mountains of Upper Egypt, the Atlas mountains, and of the country about the Cape of Good Hope. In North America, it is found in New York, Pennsylvania and Vir-

ginia. In South America, it forms whole groups of the elevated Cordilleras; and a large tract of country extending from Cape Horn, which is the southern extremity of America.

It is remarkable that in the mountainous regions of Peru, especially in the environs of volcanoes, no granite is found except in low situations, as in valleys.

Gneiss is the next oldest of the primitive rocks, and like granite, it consists of felspar, quartz, and mica; it is generally so small-grained, and the mica for the most part prevails so much, that gneiss is mostly of a slaty structure.

It sometimes encloses other rocks, as granular limestone, primitive trap, and porphyry. It contains occasionally beds of garnet, accompanied by lead ore and iron pyrites; and sometimes, though rarely, beds of slaty glance coal.

Mountains composed of gneiss are not so steep as those composed of granite; their summits are usually rounded.

There are few metals that do not occur in gneiss; in which are situated the greatest part of the Saxon, Bohemian, and Salzburgian mines.

Gneiss mostly reposes on granite, but is sometimes incorporated in it, and sometimes alternates with it. It is always stratified.

Ben Lomond in Scotland, and Mont Rosa in Italy, are almost wholly composed of gneiss, as well as the middle part of the Pyrennees. It abounds in Bohemia and Silesia, in Carinthia, in the Southern Alps, the Vosges, and in Scandinavia. It occurs also in Greece; the mine works of the ancients in the vicinity of Athens

are situated in it; it is found also in Russia, in several districts of South America, in the Shetland Islands, and in many parts of the main land of Scotland.

MICACEOUS SCHISTUS, or MICA-SLATE is considered to be the next oldest of the primitive rocks. This is also called schistose mica, mica-slate, and glimmerschieffer. This rock is composed of mica and quartz,* and like gneiss, has a slaty structure. Garnets are so commonly found in it, as to be almost considered one of its constituent parts: occasionally it contains several other substances, as hornblende, schist, and even felspar.

Micaceous schistus is distinctly stratified; and encloses the same rocks as gneiss and argillaceous schistus, which immediately precede and succeed it; as limestone, primitive greenstone, porphyry, quartz, &c. Though it usually rests on gneiss, it is not commonly found on the summits of mountains; nor does it often alternate with granite or gneiss; but generally reposes on the latter, round the sides of primitive mountains, forming gentle acclivities. The summits of hills composed of micaceous schistus are round.

It contains some ores, as gold, iron, copper pyrites, and cobalt, with garnets and asbestus; but unlike gneiss, in which they occur in veins, it contains them in beds.

The most important mines of Sweden, as those of Dalecarlia, and Fahlun; those of Roraas in Norway; many in Hungary, Salzburg, Saxony, and Bohemia, are situated in micaceous schistus; it consequently abounds in those countries. It is found in many parts of Scotland; the mountain Schihallien and the neighbour-

* For the analysis of mica and quartz, see note on granite.

ing country are composed of it. Humboldt observed it in great quantities in South America.

Argillaceous Schistus, or Clay-Slate, is a simple mountain rock,*and follows micaceous schistus in the great series of mountain rocks; but it sometimes contains thin layers of quartz or more rarely of felspar. It also contains some other mineral substances, as schorl, garnet, and hornblende; sometimes encloses other rocks.

Jameson enumerates four varieties of this rock; one of which is of roofing slate; and eight varieties of rock peculiar to the clay-slate formation; amongst which is drawing slate. To notice all these varieties otherwise than by name, does not form a part of our present object. They are whet-slate, roofing-slate, chlorite-slate, talc-slate, alum-slate, drawing-slate, potstone, and flinty-slate. These rocks usually occur in beds in the clay-slate formation: in which also limestone, porphyry, and some other rocks occasionally occur.

Argillaceous schistus is one of the most metalliferous of the primitive rocks; it abundantly contains veins and beds of tin, lead, cobalt, silver, and copper; gold, and the ore of quicksilver are said also to occur in it. It is a very widely extended rock, and sometimes forms whole mountains and chains of mountains; but not of the most elevated: they have generally a gentle acclivity.

* The three former rocks are called compound mountain rocks, being composed of two or three mineral substances, viz. quartz, felspar, and mica; but argillaceous schistus is called a simple mountain rock, because it is not so compounded. It consists of two or three elementary substances, as of silex, alumine, and oxide of iron. There are several varieties of this rock, which have not been accurately analysed.

In the Highlands of Scotland, argillaceous schistus rests upon, and passes into, micaceous schistus. On the continent of Europe it may be traced through a great extent of country; as in Saxony, Bohemia, Silesia, Franconia, Bavaria, the Alps of Switzerland, Austria, Hungary, and many other districts. It occurs in Pennsylvania in North America. It is said that nearly the whole country between Potosi and Lima in South America, is composed of it.

Saussure found it on the summit of Mont Blanc. In Britain, it occurs largely in Cornwall, enclosing viens of tin and copper; and it forms the summit of Skiddaw in Cumberland. The famous mountain of Potosi, in which are situated the great silver mines, consists entirely of clay-slate.

Primitive Limestone is the next in order of primitive rocks. It is a simple mountain rock,* and is white, yellowish, greyish, greenish, or reddish white. Its structure is always granular. The oldest, is the whitest and most granular.

It sometimes encloses quartz and mica; the latter imparts to the limestone a slaty structure; more rarely it contains garnets, steatites, asbestus, and other minerals.

Occasionally it occurs in distinct strata; or in beds,

* When lime is combined with the carbonic acid, the compound when compact, is commonly called limestone; another variety is called calcareous spar, (calx being the Latin for lime) and mountains of limestone are commonly called *calcareous* mountains.

Calcareous spar is composed of 57 parts of lime, and 43 of carbonic acid. The limestone of calcareous mountains yields about the same proportion.

sometimes short and thick, sometimes so thick as to form whole mountains.

Primitive limestone is not often found enclosed in the older rocks called gneiss, mica-slate, and clay-slate, just described. As a rock, it contains various mineral ores in beds and veins; as those of lead, zinc, and iron, auriferous pyrites, and native gold.

Whole mountains in Stiria, Carinthia, Carniolia, and in the Pyrennees, are composed of it; as well as three in Switzerland 10,000 feet high. But primitive limestone in these situations, is generally in immense blocks, without any regularity in regard to size, dip, or direction; it is sometimes stratified, as at Altenburg, near the lake Neuenburg, and in some parts of Scotland.

The marble of Sutherland in Scotland is said to be particularly valuable. The promontory of Athos in the Archipelago, is composed of primitive limestone; but the most extraordinary mass of it occurs in Spain: it is said that the mountain of Filabres, consists of one block of white granular marble, 2000 feet high, and three miles in circumference, without any mixture of other earths or stones, and almost without a fissure.

Primitive Trap: the rocks belonging to this formation are numerous. *Trap* is a german word, signifying a *stair*. The rocks of this formation are termed trap rocks, because their exposure to the elements causes them to take the form of steps or stairs.

Primitive trap is either almost wholly composed of hornblende, or of hornblende mingled with felspar: or hornblende, felspar and mica.* Hence primitive trap

* Hornblende is a mineral which occurs massive occasionally, but mostly in crystals confusedly intersecting each other: its

has been divided into three species. Ist. *Hornblende Rock*, which is almost entirely composed of hornblende, and is sometimes granular, sometimes slaty. 2d. Hornblende mixed with felspar, constituting *Greenstone*, which has been again subdivided into common greenstone, porphyritic greenstone, greenstone porphyry, green porphyry, and greenstone slate. 3d. *Hornblende mixed with mica.*

Hornblende rock is found in the Scottish Isles, in the highlands of Scotland, and abounds in Bohemia, Saxony, the Tyrol, Siberia, &c. Greenstone and greenstone slate occur in the same countries. The latter forms great beds and mountain masses, as in Sweden. Some of the Saxon and Swedish mines are situated in green stone slate. Hornblende with mica, occurs in beds in gneiss and micaceous schistus, but this rock is described as a mixture of hornblende with felspar, containing scales of mica.

Serpentine is considered the next in order of the primitive rocks : it is a simple mountain rock.*

Serpentine sometimes encloses other substances ; and among them are asbestus, mica, and crystals of quartz and hornblende. But only one instance is known in which it is incidentally mingled in another rock : serpentine with limestone forms the precious stone denominated *verd antique*.

colour is dark green, approaching to black. It is composed of 42 parts of silex, 14 of lime, 12 of alumine, 32 of oxide of iron, and some water.

* Serpentine is composed of about 45 parts of silex, 30 of magnesia, 15 of alumine, with some oxide of iron, and water.

It is considered that there are at least two formations of serpentine. The oldest, which is of the most uniform green colour, sometimes accompanies primitive limestone. It occurs at Portsoy in Scotland, at Joachimsthat in Bohemia it occurs in beds in gneiss and mica slate. It also is found in Silesia and Sweden. Though metalliferous ores are not abundant in it, they are more so than in the serpentine of the newer formation. It never occurs in very distinct strata; but generally in masses of undeterminate shape, and in beds.

The ores of lead, silver and copper, are found in serpentine, though not abundantly.

The newer serpentine formation, which is of a less uniform green colour, being more intermingled with red veins, occurs in Bohemia, Silesia and Saxony. Unst and Fetlar, two of the Shetland islands are considered to be of this formation.

Serpentine rarely forms mountains, but is said to form the summit of Mont Rosa, which is principally of gneiss. In beds, it occurs in Silesia, Bohemia, Saxony, and in the Scottish islands; and it forms a large tract of country in Cornwall, of many miles in extent, in which occur veins of native copper, and some veins of the soapstone, so abundantly used in potteries, which is sometimes accompanied by asbestus.

Some varieties of serpentine are exceedingly beautiful, and are turned to purposes of ornament. At Zoblitz in Upper Saxony, several hundred persons are employed in quarrying, cutting, turning and polishing the serpentine found in that neighbourhood; and the various articles into which it is made are carried all over Germany.

Porphyry is the next in age of primitive rocks, and is one of the most widely extended formations.

It is a compound rock, consisting of crystals of quartz or felspar, or both, imbedded in a basis which is considered to be of contemporaneous formation: the imbedding substance, in the older porphyries, is generally of hornstone or compact felspar; in the newer formations it is generally of various kinds of clay*. Occasionally, porphyries contain, as well as certain other minerals, portions of clay and agate, or chalcedony.

Porphyry sometimes contains the ores of gold, silver, lead, iron, copper and manganese; but these occur principally in the newer porphyries; always in veins, never in beds. The principal mines of Hungary are situated in porphyry.

Porphyry does not appear in distinct and well defined strata; but occurs in beds of great magnitude, sometimes indeed forming mountain masses in various parts of the world. It is said that the only rock with which it alternates is sienite.

But of porphyry, it is considered that there are two formations; the oldest occurs in gneiss, in beds of great magnitude, also micaceous and argillaceous schistus, its basis is chiefly either hornstone or felspar. The newer formation has principally a basis of clay; it is the most abundant of the two formations.

Porphyry is found occasionally in Scotland and the Scottish isles. On the continent, it may be traced from

* For the analysis of the imbedded substances of porphyry, quartz, and felspar, see note on granite. It it difficult to give that of the imbedding substances which are numerous. It will suffice to say that they are principally composed of the siliceous and argillaceous earths.

Norway to the borders of the Black Sea. It appears in Sweden, Finland, the Hartz Forest, Saxony, Bohemia, Silesia, Salzburgh, the Tyrol, Carinthia, Carniola, Greece, the islands of the Archipelago, Egypt, Siberia, and in North and South America.

Sienite is the next oldest of the primitive rocks; it is less abundant than most, if not all, of the foregoing.

It is compound, and consists of hornblende and felspar; the felspar predominates: some varieties contain quartz and mica, and but little hornblende*, others greatly resemble greenstone; but sienite is mostly somewhat red. Sienite is very nearly allied to porphyry, and is equally metalliferous.

In the island of Cyprus it affords much copper; many of the important silver and gold mines of Hungary are situated in it; it occurs in the Electorate of Saxony, the forest of Thuringia (where it abounds in iron), Transylvania, and Upper Egypt; also at Galloway in Scotland, and sparingly in England.

According to Werner, there are yet five other primitive rocks, making in the whole fourteen: these are of far less abundant occurrence than the foregoing, and will not detain us long.

Topaz Rock is composed of quartz, topaz, schorl, and a sort of clay: it is rare, having hitherto only been found near Auerbach in Germany; where it forms a mountain mass of considerable extent.

* For the analysis of hornblende, see note on primitive trap, and for the analyses of felspar, quartz and mica, see that on granite.

Quartz Rock is a simple mountain rock, occurring principally in veins and beds; but enclosing no metallic ores of any description. Sometimes it includes mica, and has then a slaty structure. Quartz occurs plentifully in certain mountains in Scotland, and in some of the Scottish isles. On the continent, quartz rock appears in Saxony, Bohemia, Silesia, Bavaria, and other places. It is however said that the mountain called Bultuc, one of the Altaic chain, in Siberia, being 350 feet high, and 4800 broad and long, consists entirely of milk white quartz; which sometimes forms spires on the tops of mountains, appearing like snow.

Primitive Flinty Slate is a simple rock; it includes two species, flinty slate and Lydian stone; both are traversed by veins of quartz.

Flinty slate occurs in beds in argillaceous schistus, and also forms mountain masses, exhibiting high and rugged rocks, as in some of the Saxon mountains.

Primitive Gypsum is perhaps the least important of all primitive rocks. It has hitherto been found only in the Alps of Switzerland, where it is granular; but being mixed with mica and clay-slate, the rock thereby obtains a slaty structure: this structure is never to be observed in secondary gypsum.

White Stone: the characteristic colour of this rock is white; it is composed of a little mica and compact felspar, and has a slaty or granular structure: sometimes it contains garnets. Hitherto it has been principally found in Saxony and Moravia: a variety of it appears in the mountains of the south of Scotland.

We have now taken a cursory view of what, according to our present knowledge of the crust of the globe, are considered to be the *oldest rocks*. All these, though some of them be occasionally found mingled, or alternating in beds or strata with each other, are *crystalline deposites*, and are *absolutely without any trace of organic remains, either of plants or animals:* for this reason, these are supposed to be in the very state in which they were deposited, and therefore have received the name of *primitive rocks*.

But the fourteen rocks of which we have taken a slight view, are not, by some geologists, supposed to form the whole catalogue of primitive rocks; jasper, hornstone, pitchstone, and puddingstone, are by some added to it: some of these appear to be essentially connected with those we have described, and the characters of the rest do not seem to be so decidedly fixed, as forming mountain masses, as to induce me to detain you by their description.

All rocks not included in the foregoing catalogue, (with the exception of those called alluvial,) have by some geologists been termed *secondary*, because they are found to contain more or less of organic remains: but it has been discovered that the four rocks found in immediate succession to the preceding fourteen, do not contain organic remains precisely of the same characters as the rest. For although the four rocks in question enclose some shells common to those immediately in succession to them, they also contain a variety of petrifactions, distinct in their characters, called zoophites, or those animals which are considered as forming the first link in the chain of animated beings; *none of which are found in any of the succeeding rocks.*

In these four rocks which contain the *first traces* of organic remains, also appear the first mechanical deposites; and Werner has termed them *transition rocks*, as connecting the *primitive*, with the *newer rocks* containing abundance of the remains of plants and animals; these newer rocks he has called *flœtz rocks*, (the word *flœtz*, meaning *flat*,) because the position in which they are found is more flat than that of the primitive or transition rocks, and is frequently quite flat.

It has already been remarked that some geologists, who are of opinion that some of the distinctions made by Werner are not necessary, class all those he has named transition and flœtz, under the general term of *secondary rocks*.

The four *transition rocks* are called transition limestone, transition trap, greywacké, and transition flinty slate.

Transition Limestone is of nearly the same colours, and frequently of the same aspect, as some varieties of primitive limestone, but its grain is much finer; in other words, it is less crystalline. It contains petrifactions of marine animals, as corallites, enchrinites, pentacrinites, entrochites and trochites, and although these are not all confined to this rock, yet they gradually disappear in newer formations; and when they do occur in the latter, they are accompanied by petrifactions that never appear in transition rocks. When transition limestone occurs in mountain masses, it forms high cliffs, and precipices, and narrow and deep vallies. It is not very metalliferous. In beds it occurs in Peebleshire, Lanarkshire and Dumfrieshire in Scotland. On the Continent, in the Hartz Forest, and in that of Thuringia, the Saxon Erzgebirge,

Silesia, Bohemia, Bavaria, the Tyrol, Italy, Salzburg, and Hungary. In England, near Plymouth. The limestone of Derbyshire is by some considered as a transition, by others, as a flœtz rock.

Of Transition Trap there are two varieties; Transition Greenstone and Transition Amygdaloid.

Transition Greenstone is principally distinguished from primitive greenstone, in being less crystalline. The hornblende and felspar are so minute and intimately mixed, that they are scarcely to be distinguished. It sometimes contains veins of quartz, which flœtz greenstone never does. It occurs in beds in Dumfrieshire, in the Hartz, Bohemia, &c.

Transition Amygdaloid consists of wacke, enclosing clay, chalcedony and agate. It appears in the Hartz, in Saxony, and in Derbyshire in the form of large beds which are associated with limestone. It is not abundant.

Greywacke is a widely distributed rock; it presents the first appearance of a mechanical deposite.

It is described by Jameson as composed of grains of sand, which sometimes are of considerable size, connected together by a basis of clay slate; but this rock, when the particles of sand are so small as to be scarcely perceptible to the eye, is generally of a slaty texture, and is then called *Greywacké-slate*.

Both these rocks contain petrifactions. They alternate with each other, and with transition limestone, trap, &c. and are distinctly stratified.

Greywacké is uncommonly productive of metalliferous ores, both in beds and veins. Almost all the mines in the Hartz are situated in it, affording silver, copper, zinc and lead. In Transylvania, greywacké is traversed

by numerous small veins of gold. It also occurs in Saxony, Bohemia, Silesia, Moravia, Switzerland, Tuscany, France, Portugal, &c. According to Jameson the lead hills in Scotland are of this formation.

TRANSITION FLINTY SLATE is of small importance; it principally occurs in considerable beds in the grey-wacké slate of Bohemia, and the lead hills in Scotland.

To the four transition rocks just described, succeed the flœtz rocks, wich are twelve in number according to Werner. It has just now been observed that the whole sixteen are frequently, if not commonly denominated *secondary rocks.*

As the position of the flœtz rocks is mostly flat, we may correctly imagine them to exist as *twelve beds, deposited one above another:* they all contain animal or vegetable remains, and are found in most countries; in many, in prodigious quantities. They are not very metalliferous; nevertheless some of them are of almost infinite value to man.

The first or oldest of these is called the OLD RED SANDSTONE, which in point of age succeeds the transition rocks, just described.

Sandstone, according to Jameson, is composed of grains of sand or gravel, connected together by means of clay, marl, quartz, or clay much impregnated with iron. Some varieties contain clay, others mica, as in the neighbourhood of some coal formations. Such sandstones as are porous are used as filtering stones. When a sandstone contains rounded masses of considerable dimension, it is termed a *conglomerate;* which generally

forms the lower part of the bed. Some sandstones, particularly in some districts of Germany, contain the remains of plants, as petrified trees, impressions of the leaves, particularly those of the nut-tree. That of the Cordilleras in America, and that of Scotland contain the remains of plants and animals, both land and marine.

In the Hartz, the old red sandstone rests on grey-wacké. It has been traced from the Hartz, through Saxony, Hesse, Bohemia, Silesia, and Franconia. It occurs also in Siberia; and some geologists are of opinion that the sandstone so abundant in certain districts of England, belongs to this formation. When the old red sandstone comes in contact with the first flœtz limestone, which is said to be remarkable for the abundance of its ores, the sandstone is intermixed with ores of various kinds.

On the old red sandstone reposes the First Flœtz Limestone. It extends round the whole of the Hartz Forest in Germany, resting on the old red sandstone. It also occurs in the Saxon Erzgebirge, Magdeberg, the Forest of Thuringia, in Hesse, Westphalia, Franconia and Swabia. It contains abundance of that species of petrifaction denominated gryphite. In Thuringia its lowest stratum is slaty, and as it contains much copper and some bitumen, it is called bituminous marl slate, and by the miners copper-slate. It is traversed by numerous veins containing ores of copper and cobalt; and sometimes beds of ironstone. The first flœtz limestone, according to Humboldt, occurs in the Andes of Peru, between latitude 6° and 7° south, and is traversed by numerous veins of silver, which have been worked since the year 1772, affording yearly 100,000 marcs.

On the first flœtz limestone lies the First Flœtz Gypsum. This formation is found in a great part of Germany; also in Bavaria, Switzerland, the south of France, and in Spain; on the banks of the Wolga, and in South America. It sometimes contains selenite and stinkstone, crystals of quartz, and rock-salt; though petrifactions rarely occur in it. In Arragon in Spain, it includes the arragonite; in Italy and on the banks of the Wolga, large masses of sulphur are imbedded in it.

On the first gypsum, rests the Second, or Variegated Sandstone; so called from its being marked with brown, red and white stripes alternating with each other.

This formation is seen every where in Thuringia. It also occurs in the districts of Mansfeldt and Magdeburg; in Franconia, and many other places in Germany.

On the variegated sandstone lies the Second Flœtz Gypsum; but these rocks sometimes alternate. It is less abundant than the first flœtz gypsum, and does not contain the minerals, as the arragonite, &c. which are found imbedded in the latter. This formation occurs in Saxony, Silesia and Bavaria; also in England.

Above the second flœtz gypsum lies the Second Flœtz Limestone; which from the abundance of petrifactions it contains, is also called the Shell Limestone. The upper beds, which are thin, contain the asterias caput-medusæ, sea-plants, and small fishes; the beds beneath contain larger fishes; then crabs of different kinds, and the lowest beds contain belemnites, terebratulites and echinites. The shell limestone sometimes contains flint and hornstone in regular layers. This

formation, in every part of the globe in which it has been seen, presents numerous caverns, which are often filled with stalactite, particularly in Franconia, Bavaria and Swabia. Ironstone, the pea-iron ore, and a great profusion of the bones of extinct animals, are also found in these caves, which are generally situated in the upper part of hills. This formation extends through Lower Saxony into France, forming the mountains of Jura. Certain mountains in Africa, Egypt, Syria, and large tracts of country in Siberia, are considered to belong to it.

On the shelly limestone rests the Third Sandstone. This sandstone differs from the two preceding formations of the same rock, in being always white, in containing some traces of coal, and in never containing gypsum. The valleys it presents are deep, rocky, and romantic; and it is remarkable in Bohemia for the picturesque scenery afforded by the numberless pillars and pyramids, single or joined together, two or three hundred feet high, over a large tract of country at Auerbach: in the neighbourhood also, caverns and grottos appear in the same sandstone, from which issue streams, that give rise to water-falls, and thus increase the beauty of the scene. This formation passes through the Electorate of Saxony, and Lusace, into Siberia and Bohemia, and surrounds, or is wrapped round almost the whole of the Riesengebirge.

On this, which is the third flœtz sandstone, rests the Rock Salt Formation. Of this extensive and highly beneficial deposite, it is my intention hereafter to give a somewhat detailed account, particularly of our vast deposite in Cheshire.

To the rock salt formation, according to Werner, succeeds the CHALK FORMATION; the earthiness of which denotes the lateness of its origin. Wherever found, chalk is always the prevailing substance, forming hills of three or four hundred feet in elevation, which are remarkable for the smooth regularity of their outline. It is far less abundant than limestone. It is chiefly found in England, France, the Netherlands, in some islands in the Baltic, in Sweden, and Poland. In England it forms long continuous hills nearly in the direction of east and west, separated by ranges of sandstone, and low tracts of gravel and clay. There are two formations of chalk, the upper and the lower; the latter is without flints, the upper, whatever may be its elevation, is characterized by containing parallel and horizontal layers of flints. Chalk contains echinites, ostracites, and belemnites, and sometimes the remains of amphibious and land animals. Of metalliferous ores, it contains only iron pyrites, here and there imbedded in small masses.

To the chalk succeeds that which is called by Jameson the FLŒTZ TRAP FORMATION, of which we have no very intelligible or distinct account.

The INDEPENDENT COAL FORMATION next succeeds. As a description of some coal districts, particularly our own, would now occupy too much time, I purpose hereafter to give some account of this valuable deposite.

To the coal succeeds that which is by Werner termed the NEWEST FLŒTZ TRAP FORMATION. The term formation,* has already been explained. The newest flœtz trap is the most comprehensive, and perhaps least intel-

ligible series of all rock formations. The rocks which peculiarly belong to it are, basalt, wacké, greystone, porphyry slate, and trap-tuff. Other rocks occur in it, but are not peculiar to it; as greenstone, amygdaloid, pitchstone, obsidian, pumice, compact felspar, clay-stone, sandstone, clay, sand, gravel, clay-iron-stone, limestone, iron clay, and coal.

Basalt is of a greyish black colour, heavy, and hard. It occasionally contains olivine, augite, mica, &c. or is mixed with pitchstone, marl, and indurated clay, or contains rolled pieces of quartz, gneiss, &c. and sometimes petrifactions. At Vicenza in Italy, ten beds of basalt alternate with the same number of beds of limestone. In veins, it traverses granite, gneiss, micaceous schistus, and most of the secondary rocks, including coal. The huge pillars of the Giant's Causeway in Ireland, are of basalt; which also covers the summits of the Erzgebirge, or metalliferous mountains, separating Bohemia from Saxony, which are 120 miles long and 3000 feet high above the sea. The basalt sometimes rests on some of the older rocks, sometimes on sand, gravel and clay:* it is common in Scotland.

Wacké is by Werner considered to be intermediate between basalt and clay. When it contains hornblende and mica, it approaches basalt. It forms in the opinion of some geologists, the basis of amygdaloid or toadstone. It occurs in beds and veins, the latter sometimes contains small portions of the ores of silver, bismuth and iron. Wacké very seldom contains petrifactions.

Greystone, according to Werner, is a mixture of white felspar and blackish hornblende; the former predomi-

* The basalt of Saxony is composed of about 44 per cent. of silex, 17 of alumine, 9 of lime, 2 of magnesia, 2 of soda, 20 of oxide of iron, 2 of water, and a trace of oxide of manganese.

nates. It contains olivine and augite, which in the estimation of Jameson shews the affinity of greystone to basalt; into which, he observes, it sometimes passes.

Porphyry-slate is a compound rock, consisting of clinkstone, enclosing crystals of glassy felspar, occasionally of basaltic hornblende, zeolite, &c. It occurs in great abundance in Bohemia; also in Lusace, in Swabia, &c.; the Braid hills near Edinburg, and in the islands of Arran and Lamlash in the Frith of Clyde; and in other parts of Scotland. Of metalliferous ores, it contains only iron pyrites and iron sand in small quantity.

Trap-tuff is composed of masses of basalt, amygdaloid, hornblende rock, sandstone, and even pieces of wood, cemented together by a clayey basis, the result, as it is supposed of the decomposition of basalt or wacké. It occurs in masses of variable dimension, in beds from a few inches to several fathoms in thickness, which are mostly horizontal, and which sometimes alternate with basalt. A considerable portion of Arthur's seat near Edinburgh, is trap-tuff, which there rests on inclined strata belonging to the oldest coal formation. It also occurs in the islands of Mull and Canna, and in many other places in Scotland. Also in Bohemia, Fulda, Westerwald, &c.

The rocks which are not peculiar to the newest flœtz trap formation, but which occasionally form a part of it, as already enumerated, need not detain us long. The *greenstone*, is composed of hornblende and felspar, and differs chiefly from that described already as a transition rock, in being less crystalline. The *amygdaloid* is not described as differing from that which from its situation, principally, has already been described as a transition rock. Both *pitch-stone* and *obsidian* are by many

mineralogists considered as volcanic rocks: they have been found passing into each other. But there are many varieties of each. Some are decidedly volcanic; others, from their geological situation, it is impossible to attribute to volcanic origin. It is asserted by Jameson that *pumice* is not always a volcanic product, because it has been found alternating with basalt and porphyry. The other rocks which occasionally, according to Werner, form a part of the newest flœtz trap formation, either have already been noticed, or will be so in treating of alluvial deposites.

These are the twelve formations, which according to Werner, succeed each other in the order just described. By this we are not to suppose that we shall, in every place in which one of them is found, invariably find the rest: frequently many of them are wanting. In the sketch of the Brocken mountain, it will be noticed that the two primitive rocks, gneiss and micaceous schistus, are wanting. All therefore that we mean to say, in pointing out their successive formation, is, that if gneiss and micaceous schistus had occurred, they would have been situated between the granite and the limestone. So with the flœtz rocks: if for instance we arrived at a bed of rock salt, we might possibly find it resting on a bed of the old red sandstone, although no fewer than six formations have just been described as *newer* than the old red sandstone, and *older* than the rock salt: but had these six formations occurred, they would have been found between them; and most probably in the order laid down.

But there is still another species of deposite of which we have to speak, improperly classed among rocks,

which is invariably found above all other strata. I allude to ALLUVIAL DEPOSITES.

This class includes those substances that have been formed, and still are forming, in every quarter of the globe, from previously existing rocks; owing to the action of air and water upon them. Alluvial deposites occur both in mountainous regions, and in flat countries; filling up hollows in the first, and forming plains in the second.

In *mountainous countries* they consist of rolled masses, principally of gravel or sand; sometimes irregularly heaped, sometimes forming beds, and containing fragments of ores, and some kinds of precious stones.

The disintegration of the surfaces of hills in some parts of Cornwall, affords an extensive illustration of the effects ascribed to the agency of air and water. Large deposites of tin ore, covered by the ruins of granite, are found in many places; and have afforded rich harvests to the miner. In one of the branches of Falmouth Harbour, the miner, after damming out the water, sunk through a bed of alluvial matter fifty feet in thickness; at the bottom of which was found a bed of rounded masses of tin ore, varying from two to ten feet in thickness; in which occasionally were mingled small grains of gold. It may be conceived that the ruin must have been great, when it is known that the profits reaped from the undertaking amounted to at least £50,000. At the bottom was the solid rock of argillaceous schistus, on which I have walked.

The diamond is found in alluvial soil in the East Indies and South America, as well as the topaz and the hyacinth; and gold on the coast of California.

In *flat countries*, sand, loam, clay, sulphur, bog iron ore, and beds of gravel, are found in alluvial soil.

In the loam and sand, great beds of bituminous wood sometimes occur; of which the great underground forest in Prussia is a remarkable instance.

The remains of plants and animals are found only in those rocks which are newer than those termed primitive, and rest upon them. Such remains however occur in very variable proportion, and even in some of the older secondary (or transition) rocks, no vestige of them occurs.

It has already been remarked, that in the transition rocks, which rest immediately on primitive rocks, occur the remains of animals called zoophites, which form the first link in the chain of animated beings. These seem to be most abundant in transition limestone; in which also corals of different species are found, approaching very nearly, in external characters, to those now growing in tropical climates.

In transition trap and flinty slate, no organic remains are to be seen.

Greywacké and greywacké-slate seldom contain petrifactions; in large tracts of country consisting of these rocks, not a trace is to be seen; in others, some few are found, both of animals and vegetables. The animal remains are nearly the same as those found in the limestone. In greywacké it is said that the remains of animals of the serpent kind also occur: the vegetable petrifactions appear like the stems and leaves of palm trees, and of reeds. Greywacké-slate contains the remains of those remarkable corals, which are supposed to form the connection between shells and corals.

The old red sandstone is the oldest of the flœtz rocks: it contains but few petrifactions, principally of trunks and branches of trees, which resemble those of tropical climates.

The first floetz limestone comprehends three or four varieties of rocks, in each of which animal and vegetable remains are found: some of these belong both to salt and fresh water; the remains of a large amphibious animal of the genus monitor, have also occurred, which have been described by Cuvier.

All the other floetz rocks contain abundance of animal remains, except the gypsum and trap formation, in which they are rare: several of them also enclose vegetable remains. In the second floetz limestone, are found petrified fishes of various genera and species, and fossil amphibious animals; the stems and leaves of trees, and of flowers, as of the ranunculus. In the third floetz or shell limestone are found, together with prodigious quantities of shells, the fossil remains of fishes and of birds. Chalk sometimes contains the teeth and bones of fishes and the remains of tortoises and crabs.

In alluvial formations, petrifactions are distributed, which often are so much rounded as to show that they have suffered by attrition: the organic remains are those both of fresh and of salt water, and also of land and of amphibious animals. The shells of oysters and of muscles are plentifully found; occasionally the teeth of sharks. In some places, the bones of the horse, the ox, and the stag occur, but differing from those of the living species; in others, the bones of elephants similar to those now inhabiting Asia and Africa, and of the rhinoceros and hippopotamus; in others again, the bones of several extinct species of the elephant; and of an elk, formerly an inhabitant of Ireland.

LECTURE V.

Of Mineral Veins—Of Salt Deposites—Of Coal Deposites—Of Volcanoes—Of the Deluge—Of the Internal Structure of the Earth—Concluding Observations.

OF MINERAL VEINS.

In treating of veins, we have a two-fold object. They merit our attention in respect to the extraordinary circumstances which attend them in all countries in which they occur; and also on account of their being the *chief mineral deposites.*

But mineral deposites are of two kinds: for metalliferous ores are largely found in beds, as well as in veins.

Mineral beds are for the most part horizontal; and are found both in primitive and secondary countries, of various elevation.

The ores of copper, iron, and lead occasionally occur together in beds in primitive mountains; and sometimes gold and silver are intermixed with them. Cobalt, and certain ores of mercury, also occur in beds. Almost all the metalliferous ores in the great mining district of Sweden, are in beds in primitive mountains. Lead, zinc, and iron ores occur abundantly in beds in secondary mountains.

In England, some ores are found in beds; but by far the greatest mineral deposites of this country are in veins; it is uniformly the case in Cornwall.

A vein may be described as a *fissure* that has been afterwards filled up with several different substances.

Humboldt observed a vein of calcareous spar 140 feet wide, traversing gneiss in the Alps of Switzerland. Jameson observed a vein of porphyry-slate traversing sandstone, in the Isle of Arran, nearly 160 feet wide; and in Scotland, veins of pitchstone and greenstone, from 10 to 100 feet wide. But these veins do not appear to have been what may be termed *metalliferous veins;* which for the most part, are much narrower.

It is said that in most *primitive* metalliferous mountains, veins extend but a few hundred fathoms in length, and that their width does not exceed two feet.

It has also been said, that a description of the veins of Cornwall would, generally speaking, suffice for those of almost every other country; and having heretofore given much attention to their actual state, I shall confine myself chiefly to them, and endeavour to give a general outline of their direction, length, depth, width, dip and contents.

But in these respects, veins have not such an uniformity, as that the history of one would be an history of the rest: almost every vein has something peculiar in it; something to interest the geologist.

The *metulliferous veins* of Cornwall, that is, the veins producing copper and tin, which are the chief mineral productions of the county, run in the direction of nearly *east and west;* they may vary a few points. There are however other veins, that *rarely contain any metallic substance*, which for the most part run *north and south.* These two facts are extremely curious.

Metalliferous veins may sometimes be traced along the surface of the earth, by a certain ochreous or rusty appearance; but this is not very common.

A vein may be said in some sort to resemble a deep cleft or crack in a field. This cleft, whatever might be its depth, must of course have a direction under ground: either it would be quite straight down, or it would have a slanting direction beneath the surface.

The veins of Cornwall scarcely ever take a direction quite straight down, or, in other words, quite at right angle with the horizon; but almost always dip, or incline away from that angle.

So that the metalliferous veins which run east and west, dip or underlie either towards the north or south; and the non-metalliferous veins, which run north and south, dip either towards the east or west.

The length of no one vein in Cornwall has as yet been satisfactorily proved. Some of them have been traced two, or three, or even four miles; but no instance has occurred in which a vein has been known to stop. Nor has the miner ever yet seen the bottom of a vein. The length and depth to which veins extend, therefore, are not known. There are several mines in Cornwall upwards of 1000 feet in depth from the surface, and two or three nearly, if not quite, 1300 feet deep.

Metalliferous veins differ exceedingly in regard to their width. A vein containing tin ore, in a mine called Whealan Coates, was only three inches wide, but was so rich as to be worth working; while another, in a mine called Relistian, was upwards of 30 feet wide, and was also very rich in tin. Some of the veins containing copper in Herland mine, did not exceed 6 inches in width; and so continued for a few fathoms, but eventually passed away east and west in mere strings, scarcely thicker than paper; but these veins yielded copper of a very rich quality. A copper vein in the next hill, varied

from 12 to 24 feet in width, and was also very productive of copper.

But the generality of metalliferous veins, both of tin and copper, are from one to three feet in width: and these are preferred by the miner, because the ore they contain is generally less intermixed with other substances, than that of wider veins.

Hitherto we have been speaking principally of metalliferous veins. There is yet one circumstance, and a very important one, in regard to these, that we must not fail to notice. These veins are not *filled* with metalliferous ores. The ores both of copper and tin principally occur in quantities which, though they may extend many fathoms every way, generally occupy, in point of fact, but a small comparative portion of the vein, and are therefore properly enough termed *bunches*.

A question here naturally arises. With what substances are the remaining parts of the veins filled up? These are occupied sometimes by rocks, or by stony or earthy substances of various descriptions; or by rubble, or refuse matter that seems to have resulted from the ruin of some parts of the neighbouring country. The non-metalliferous parts of a vein, of whatsoever composed, are commonly termed by the miner *deads*, because they yield him nothing. Sometimes, however, veins are found to have large empty spaces; but this, in Cornwall, is not common. Water is very abundant in veins, particularly in those rich in tin or copper. On a large mine it is not unusual to see two or three steam engines, for the purpose of drawing the water. These will raise and discharge into the neighbouring valley, at least 1000 gallons of water every minute, night and day.

The sides of metalliferous veins are generally very

determinate; and are covered by a hard dark-coloured crust, called by the miner the walls of the vein: and there generally runs down every vein, a small vein of a whitish clayey substance, which sometimes adheres to one, sometimes to the other wall.

The ores of copper and the ore of tin (for of tin there is but one description of ore, while there are many of copper) do not often occur together in the same vein to any great depth beneath the surface.

At about 80 or 100 feet under the surface, the first traces of copper or tin are usually found; rarely nearer to it than 80 feet. But when at last they are found, it is not to be understood that these ores consist of one close and compact mass: on the contrary, they are generally mingled with other substances, such as lead ore, iron pyrites, and the ore of zinc, accompanied by fluor spar, quartz, &c. These are in some cases loose in the vein; in others, they are hard, and attached to one or to both sides of it.

Sometimes the ores *both* of tin and copper are found thus circumstanced *together* in the same vein; and when so found, it generally happens that all trace of tin is soon lost.

If tin be first discovered, even without a trace of copper, it is not unusual, that in the course of sinking 80 or 100 feet more, all trace of it is lost, and copper only is found. The vein of course was at first called a tin vein; but afterwards became only a copper vein: and many of the most productive mines in Cornwall have been exactly so circumstanced. Nevertheless, in some veins, tin continues to be found to the great depth of nearly 1000 feet beneath the surface, almost without a trace of copper.

But if, instead of tin, copper be first discovered at the depth of 80 or 100 feet, it seldom or ever happens that tin is found below it in the same vein.

In one or two of the deepest mines in the county, both copper and tin have continued down together, in the same vein, to the greatest depth at which it has been seen by the miner; sometimes one prevailing, sometimes the other.

It has been stated that the *tin and copper veins run nearly east and west;* but that the *veins which run nearly north and south, scarcely ever contain a trace of tin or copper:* in some few instances, they have been found to contain the ores of silver, lead, cobalt and iron; others have produced antimony.

These north and south veins are usually filled by quartz, or a whitish or bluish clayey substance, or an ochreous substance; and sometimes by all three. When a vein of this description meets with a vein containing tin or copper, it *passes through the tin or copper vein*, and sometimes, as it were, splits it into numerous little branches; the north and south vein continuing its course straight forward without interruption.

Not only is this curious effect produced, but also another of a much more extraordinary nature. In searching for the tin or copper vein on the other side of the north and south vein, it sometimes cannot be found for a length of time, nor without much labour and expense: forty years have been spent in such a search.

For, instead of continuing its course, instances have been known in which the tin or copper vein has been again found 120, or even 450 feet, north or south of that part of it, on the other side of the north and south vein.

North and south veins vary in width from one inch to

ten or twelve feet; but whatever be their width, they always divide tin or copper veins, and generally alter their course; or, in the language of the miner, *heave* them out of their course.

In some parts of the mining districts of Cornwall, metalliferous veins are so numerous, that with the miner, the question is not where a vein can be found, but where he will be most likely to meet with one productive of copper or tin. Years of labour and large sums of money are often expended in vain, because there is no circumstance by which he can determine with certainty that his efforts will be successful.

There are many mines through which several veins of copper and tin take their course very near to each other.

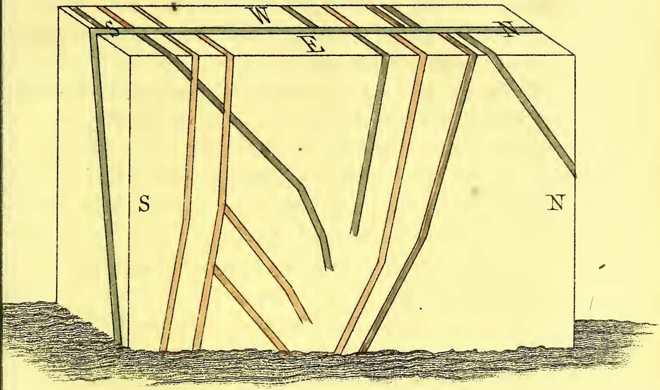
If a copper vein meets with a tin vein, it is universally the case that *the copper vein passes through that of tin*, and generally heaves it out of its course, greatly to the inconvenience and loss of the miner, who is often puzzled to find it again.

There are still other, and if I may so say, subordinate veins found in Cornwall. The explanation of their nature and effects would trespass too greatly on your time: they rarely contain any metalliferous substance, but they occasion prodigious vexation and expense to the miner.

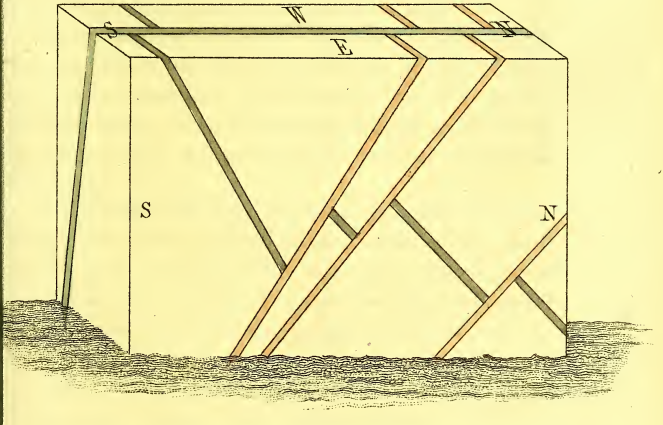
In elucidation of what has just been said of the phenomena attending the veins in Cornwall, I shall offer for your inspection a sketch of those which actually occur in two mines called *Tin Croft* and the *Pink*, (see plate 4.) Let us suppose that the upper square figure represents the hill in which Tin Croft mine is situated: it is not an exact representation of it, because that hill

Plate 4.

Veins in TIN CROFT Copper & Tin Mine.



Veins in the PINK Mine.



has a gentle declivity on every side; but for the sake of familiar illustration, I have supposed it to be cut away on the north, the south, the east and the west sides, and that the soil is taken from the surface down to the rock, in order more clearly to show the run of the several veins upon it, and their directions beneath it.

All these veins are found in Tin Croft mine, in less than half a mile from north to south. The upper part of the square figure represents the field in which the mine is situated. We shall observe that there are three veins of copper (coloured red); three of tin (black); and one yielding both copper and tin (red and black). These veins run on the surface east and west, and are intersected by a vein running north and south (bluish) which is not metalliferous; and we shall further observe that the copper and tin veins were not merely intersected, but also, that the parts of them on the western side of the north and south vein, were 'heaved' out of their regular course towards the south.

Let us remark the downward direction of the copper and tin veins; not one of them runs straight down; they dip or underlie more or less either towards the north or south. Two of the copper veins intersect one of the tin veins, and pass through it without altering its direction.

It has been said that the miner has never seen the bottom of a vein. Three of the veins in Tin Croft seem to stop; the fact is that the miner did not pursue these veins to so great a depth as the others; their direction beneath where they seem to stop is not exhibited, because it is not known.

From one of the copper veins which underlies a little towards the south, two branches go off underlying

much quicker towards the north : the veins of Cornwall rarely branch off in this manner.

The section of the Pink mine is a remarkable instance in proof of the assertion that *copper veins meeting with those of tin, always divide, and pass through, and mostly 'heave' them.*

Let us first notice the summit of the lower square figure (pl. 4.) which represents the run of the veins on the surface of the Pink mine ; in which there were four east and west, or metalliferous veins, two being of copper (coloured red), and one of tin (black). These veins were intersected by a north and south vein (bluish), that was not metalliferous ; which heaved the parts of the copper and tin veins on the western side of it, more towards the north than are those parts of them on the eastern side of it.

The tin vein ran near the southern extremity of the mine, underlying in its downward direction greatly towards the north. It will be noticed that the copper veins underlie in the contrary direction, that is, towards the south. One of them, meeting with the tin vein in its course, interrupted it, and 'heaved' that part of the tin vein on the north of the point of intersection, twenty-four fathoms nearer the surface. It was afterwards found that the tin vein was again interrupted by another copper vein, and again heaved towards the surface, though only about ten fathoms : a third time it was cut through by still another copper vein which does not appear on the surface of the mine, and again heaved, though less than before, towards the surface.

There are yet some important points respecting mi-

neral veins, on which I purpose saying a few words. I mean in regard to the probable manner in which they were formed, and by what means they were filled.

They who contend that the great masses of the globe are altogether what they now are, *by the agency of fire*, assert that veins were formed by the contractions which took place in those masses while cooling, and that they were filled from below: in other words, that the contents of veins were protruded into them from the internal parts of the globe by the agency of fire.

Those who, on the contrary, contend that the great masses of the globe are what they now are *through the agency of water*, assert that mineral veins were originally open fissures or rents, caused by the subsiding of the great masses of the globe; and that these fissures were filled from above, receiving into them the metals which formed a part of a great chaotic fluid.

I am not now about to enter into an examination of the comparative merits of these two doctrines, but shall probably hereafter say a few words on this part of the subject.

I cannot however pass by one or two observations in regard to the relative ages of veins.

It has been said that copper veins meeting in their course with those of tin, always divide and pass through them. This seems clearly to shew that tin veins are the oldest, or they could not have been so divided.

It has also been said that the north and south or non-metalliferous veins, always divide the veins of copper as well as those of tin. This clearly shews that the tin and copper veins are both older than the north and south veins, or they could not have been so divided by them.

But other veins, not containing any metallic substance, are occasionally found; which, as they divide and pass through every one of the fore-mentioned, are therefore of still later formation.

OF SALT DEPOSITES.

It was stated during the last evening that deposites of salt are principally found amongst those which are by Werner termed the flœtz or flat rocks; but which, by other geologists, are ranked among those called secondary rocks.

Clay, sandstone and gypsum, almost invariably accompany rock salt, either above or below it; sometimes both above and below it.

The countries in which large deposites of salt are found, are for the most part flat; they do not often exceed that elevation which is termed hilly.

In Germany, but few instances of the rock salt formation occur; but it is said that an uncommonly great deposition of it may be traced with little interruption from the Black Sea nearly to the Alps. It abounds in Spain; but is not very common in Russia or generally in northern countries. Nevertheless there are said to be two whole mountains in Astracan entirely composed of it. It is abundant in Persia; the isle of Ormus in the Persian Gulph almost wholly consists of rock salt. Whole mountains of it also occur in Tunis and Algiers, in Africa. It is found in New South Wales; and not long since a mountain of salt of an immense height was discovered near the Missouri river in America, eighty

miles long and forty-five miles wide, the surface of which is barely covered with earth; neither tree nor shrub is growing upon it.

But many countries are nearly without salt. At Delhi and Agra, the capitals of Hindustan, its price is 2s. 6d. per pound: and it is said to be so scarce in the interior of that country, west of Thibet, that the natives use cakes of salt, sealed up and bearing the stamp of their prince, as money.

Perhaps the most extensive deposition of rock salt in the world occurs in Wielitska, near Cracow in Poland, at the northern extremity of a branch of the Carpathian mountains. It has been worked as a mine since the year 1251, and its excavations are said to extend more than a league from east to west. The salt is of an iron grey colour, in which are found cubes of a pure white.

This mine was visited by our countryman Wraxall; from whose account of it some idea of its vastness may be gathered. He says, 'After being let down by a rope two hundred and thirty feet, our conductors led us through galleries, which for loftiness and breadth seemed rather to resemble the avenues to some subterraneous palace, than passages cut in a mine: they were perfectly dry in every part, and terminated in two chapels composed entirely of salt, hewn out of the solid mass. The images which adorned the altars, as well as the pillars and ornaments, were all of the same transparent material; the points and spars of which, reflecting the rays of light from the lamps which the guides held in their hands, produced an effect equally novel and beautiful. Descending lower into the earth by means of ladders, I found myself in an immense hall or cavern

of salt, many hundred feet in length, breadth and dimensions, the floor and sides of which were cut with exact regularity. One thousand persons might dine in it without inconvenience, and the eye in vain attempted to define or trace its limits. Nothing could be more sublime than this vast subterraneous apartment, illuminated by flambeaux, which faintly discovered its prodigious magnitude, and left the imagination at liberty to enlarge it indefinitely.'

Hitherto we have not mentioned the deposites of salt, and the salt or brine springs, which are so abundantly found in our own country. A description of some of these is my principal object. The chief are those of Droitwich in Worcestershire, and of Northwich in Cheshire, which are the most productive.

I proceed first to the *brine springs* at Droitwich.

These springs are said to be mentioned in the Domesday Survey, which was finished in 1087.

The prevailing rock around Droitwich is a brownish red sandstone, considered by some to be the old red sandstone of Werner.

At this place the brine springs are four in number, all situated within a square furlong; and as no new pit has been sunk within the last thirty years, we have not a very accurate account of the strata through which they passed, before they arrived at the brine. From the account given by Dr. Nash in his history of Worcestershire, we gather these facts: that four pits were variously sunk through from thirty to fifty-five feet of soil and rock, when they arrived at a stratum of gypsum varying from 102 to 150 feet in thickness; on passing through this, they suddenly arrived at the salt brine,

which, immediately on their arriving at it, rose quickly to the surface and overflowed. In each of the pits the brine was twenty-two inches in depth: in each also it was ascertained that it was immediately resting on a body of rock salt. Into this rock salt they bored two feet and a half without passing through it; the brine being their object.

From this account, the principal information we gather, is, that the water of these springs is impregnated with salt, by a body of rock salt; and that, as the brine rises perhaps 180 feet to the surface and overflows, the source of these springs must be situated in much higher ground than that in which the pits are sunk. The brine is perfectly limpid, and contains about one-third its weight of salt.

The quantity of brine which issues from these four pits is immense. That which is used, bears but a small proportion to that which runs to waste: nevertheless, the quantity of salt annually made from these four pits is about 16,000 tons; two thirds of this are consumed in England, and pay a duty of about £320,000 per annum. The market price of the salt is £31 per ton, £30 of which is duty.

We come now to the great beds of rock salt at Northwich in Cheshire.

These beds are known to extend one mile and a half, north-east and south-west, and are upwards of three quarters of a mile wide: there are two beds lying one beneath the other.

The strata above the upper bed, consist of gypsum, and of alternating beds of variously coloured marl, red, blue and brown; some of them are so porous as that it

has been ascertained, that 360 gallons of water rise through them in a minute; a circumstance that greatly impedes the sinking of the pits. It is remarkable, but it is well ascertained, that the various strata above the upper bed of rock salt contain no marine fossils. These strata are from 105 to 120 feet thick; they repose on the first bed of salt which is from sixty to ninety feet thick: between the first and second beds of salt lies a stratum of indurated marl, thirty-six to forty feet in thickness. So that the surface of the second or lower bed of rock salt is about 220 feet from the surface of the land. Into this second bed of salt they have sunk 132 feet, without having found the bottom of it.

The salt of these mines is for the most part of a reddish hue, arising from some admixture of iron; and it is generally so hard, that the blast by gunpowder is employed in breaking it down. The lower part of the lower bed is the purest; and in it there are considerable cavities about 16 feet in height; in which, occasionally, pillars of salt are left, six or eight yards square, which form the supports of the roof. The cavities are worked into aisles or streets; which, when illuminated by candles fixed on the sides of the rock, give a brilliancy of effect that is singularly striking; and, it is said, almost appear to realize the magic palaces of the eastern poets.

Some idea of the vast magnitude of the Cheshire salt deposites may be formed, when it is mentioned that its many mines yield 16,000 tons for home consumption annually, and that 140,000 tons more are annually exported from Liverpool.

We come now to the consideration of the means by which these vast formations of rock salt were deposited.

It must be obvious that all that can be said will amount to no more than theory: a theory which presents some objections, while its basis seems reasonable in itself.

The Cheshire salt beds occupy vallies surrounded by hills of secondary formation; and the upper surface of the bed of salt is about 40 feet below low-water mark at Liverpool. The numerous facts already adduced, have led us decidedly to adopt the belief that the sea must have stood at an elevation greatly above the general level of the earth. Is it not therefore reasonable to presume that these beds of salt were deposited by the sea; and that the beds of clay lying between and above them resulted from the ruin of rocks?

The arguments in support of this theory are,

That the upper surface of these deposites *of salt*, is 40 feet under low-water mark.

That, in the beds of marl, it is not unusual to find fragments of the older rocks; such as large portions of granite, shewing marks of attrition.

That these deposites of rock salt contain some salts, as the sulphate of soda, which also is found in the waters of the ocean.

The principal argument against this theory is, that no sea shells or weeds are found above or below these beds.

But perhaps we ought to take into consideration that there are beds of salt near Salzburg in Austria, which are stated by Von Buch to be 2975 feet above the sea; and that the salt mines in the Tyrol are yet higher.

We have however heretofore produced evidence that the sea has been at much greater elevation than this;

and has deposited almost entire strata of sea shells, at such elevations.

OF COAL DEPOSITES.

Deposites of coal are not only of great importance, but are far more abundant and more general than they are commonly supposed to be.

Coal, in greater or less quantity, and of different qualities, is found in most countries: in Holland, Germany, Saxony, Portugal, Switzerland, Sweden, China, Japan, New Holland, and in North and South America. Buffon states that in his time there were no fewer than 400 collieries worked in France. The deepest coal mine in the world is near Namur; it is stated to be 2400 feet, or nearly half a mile, in depth.

Coal is found at various elevations, but almost all the greatest deposites are in low situations; where it occurs in beds lying over each other, of various thicknesses, having between them one or more earthy deposites, or beds of stony matter. It is remarkable that though these beds of coal are nearly horizontal, they are not quite flat, but generally dip near the middle, where they are found thicker than at the sides; so that a section would give the idea of the form of a boat.

Both in this country and in others, coal is found at elevations much above the sea; and at one place in France, the strata, instead of being, as is usual, nearly horizontal, are nearly vertical. I have lately been informed that there is a considerable deposite of coal in

the immediate neighbourhood of the great silver mine of Jauricocha in Peru, which is about three miles above the level of the sea.

But it is considered that there are three formations of coal. I shall begin with the newest, on account of its being of the least importance.

The *newest coal formation* occurs in alluvial soils. In this the strata of coal are not parallel with each other; and the earthy strata that are found with it are those of sand, clay, and gravel. The newest coal consists almost exclusively of earthy brown coal, and bituminous wood, of which there is a considerable deposite near Exeter. The newest coal formation occurs also in Germany, Denmark, the Ferroe islands, Greenland, Prussia and Italy.

The *coal formation*, *next* in point of age, occurs in that deposition to which Werner has given the name of the newest flœtz trap; the result, as he conceives, of deluges. In this the coal is generally covered with clay, or basalt, in which are found neither vegetable impressions nor animal remains. The strata are not so numerous as in the formation presently to be described, nor are they so perfectly parallel with each other. The chief collieries of Scotland, of the central part of France, and of Bohemia, are of this description; these yield principally the varieties termed pitch coal and moor coal, not often slate coal.

The *oldest* is called the *independent coal formation*, because the individual depositions or beds, not being connected, are independent of each other. This formation consists of extensive and remarkably parallel strata of coal, covered by strata of indurated clay called shale, containing the impressions of vegetables, and

sometimes the remains of fresh water shell-fish. The shale is always wanting in the *newer* deposites of coal already described, but always accompanies the *oldest*. The great coal deposites of our own country, are principally of this latter description; in some of these there are as many as twenty beds of coal, varying in thickness from 6 inches to 6 or 8 feet. Between the beds or strata of coal, is one or more beds or strata of various coloured sandstone, clay, bituminous shale, or rubble stone, (called by the miners rotten stone) or argillaceous iron ore, or of secondary limestone. This formation of coal is also plentifully found in some of the countries already enumerated; and two circumstances are worthy of notice. The first, that the strata occurring above and below this formation, are in all countries very much alike, if not absolutely the same: the second, that although the shale, already described as lying above the coal, contains impressions of vegetables, and the remains of fresh water fish; it is remarkable that in every country the strata of various substances which lie between the strata of coal, scarcely ever contain any vegetable impressions or organic remains.

During the last evening, in speaking of what may be termed *the order every where observable in the disposition of the great masses which form the crust of the globe*, it was stated that deposites of coal are principally found resting upon secondary rocks: and this is proved to be the fact in respect of our own great deposites, as well as those of other countries.

Our own deposites are our immediate objects.

Three extensive collieries in Flintshire in North Wales, those of Glamorganshire in South Wales, of Coalbrookdale in Shropshire, and of Kingwood near Bristol, all

commence in the immediate vicinity of secondary limestone; and the still more extensive deposites in the North of England, at Newcastle and Whitehaven, rest upon secondary sandstone, abundantly used as grindstones.

These two extensive collieries of Newcastle and Whitehaven, situated, the one on the north-east and the other on the north-west coast, it is now confidently believed, from the great similarity existing in their strata, form but one deposite, consisting of many strata, which extend directly across the island from one place to the other; and even far beyond each, beneath the sea. At Whitehaven the workings extend a mile under the ocean, at about 600 feet below its bottom; and it is asserted that the quality of the coal is still improving as the miner advances in this direction.

From this great deposite of coal alone, it is calculated that 28 millions of tons are raised annually; nevertheless, it is also calculated that enough yet remains for the consumption of 1000 years to come.

A mere list of the strata that have been cut through to the depth of the mines at Whitehaven and Newcastle, would form a dry and uninteresting detail.

In the Restoration pit in St. Anthony's colliery at Newcastle, which is 810 feet deep, the miner passed through 73 strata of various substances; of which 16 are coal. The first 6 strata of coal do not exceed 8 inches in thickness; 2 are 1 foot thick; 6 varied from 1 foot 6 inches to 4 feet; 1 is of 6 feet; and the thickest, which is the lowest, is of the thickness of 6 feet 6 inches.

In a mine at Preston Hows at Whitehaven, which is 642 feet deep, the miner passed through 117 strata, of

which 17 are coal; the thickest of these, which is the lowest, is 7 feet 10 inches.

All that can be said upon the origin of coal must be theoretical, and perhaps very remote from the truth: it is however certain that there are few, if any, varieties of coal, which do not present more or less of the texture of wood. This appearance may be traced from the bituminized wood, which still bears, though approaching in its nature to coal, the trunk, the branches, and even in some instances the very leaves of trees, through all the varieties of coal, into the most compact, slaty kind, of the oldest formation. In some, particularly from certain districts, the fibrous texture of wood is certainly remarkable; and the greater part of those who have given their attention to the probable origin of coal, consider it to have resulted from vegetable remains.

That there still exist great underground forests is unquestionable. That in Prussia, yielding amber, may be quoted as an instance: and if coal be really of vegetable origin, this forest may hereafter in part yield important service to man, in the shape of coal. The immense bridge, not less than three miles in length, now existing and still receiving additions, on the Missouri, a river in North America, and consisting wholly of the trunks of trees, stopped in their progress down that river, may furnish coal to nations after the lapse of thousands of years.

But though some varieties of coal seem unquestionably of vegetable origin, certain others are not referable to it so decidedly; especially the slate coal of the oldest formation. This is frequently found in fragments of determinate shapes, particularly in that of a four-sided rhom-

boidal prism, presenting angles agreeing perfectly in measurement with those of crystals of mica.

Upon the whole it must be acknowledged the origin of coal is yet but little understood.

OF VOLCANOES.

On the subject of volcanoes so much both of fact and of theory has been written, that it is extremely difficult to compress into a narrow compass, any satisfactory detail respecting them or their origin.

Scientific writers have divided volcanoes into two kinds: pseudo or false volcanoes, and true volcanoes.

Pseudo volcanoes usually occur in low situations, sometimes in hilly country. They are discoverable by a sensible heat, sometimes by smoke; more seldom by flame. Sulphureous deposites and warm springs occur in their vicinity.

Pseudo volcanoes are almost always situated in the independent coal formation, and are considered to be caused by the spontaneous or accidental inflammation of beds of coal. Volcanoes of this description are to be observed in Bohemia, in Scotland, in England, and many in Kamschatka.

Of *true volcanoes* the number is considerably great. From the accounts of travellers, it appears that the whole number now in existence, most of which are occasionally in a state of activity, amounts to 193. They are thus distributed, according to Jameson, but it seems doubtful whether some pseudo volcanoes are not included.

Continent of Europe	1
European islands	12
Continent of Asia	8
Asiatic islands	58
African islands	8
Continent of America	87
American islands	19

In almost every country hills are found which, from their shape, and the character of the surrounding masses, have by some authors been considered as extinct volcanoes: many of these are no longer supposed to be of volcanic origin; but it is certain that in Auvergne, and in some other districts in France, as well as some in Spain, the remains of volcanoes are still to be seen; because the nature of their masses is indisputably volcanic.

Volcanoes are found at almost every elevation between the level of the sea and that of Cotopaxi in South America, which is 18,880 feet above it. Indeed in many instances volcanoes have burst from the bottom of the sea. Not long since a considerable island was thus formed in one night, in the great Southern ocean; and many islands in the Archipelago, as for instance, that called Santorini, which is eight miles long, owe their origin to submarine volcanoes. The island of Teneriffe is about 45 miles in length, and 20 in breadth. There is an interesting and valuable memoir in the 2d vol. of the Geological Transactions,* describing a visit to the summit of its peak, which rises to an elevation of 11,000 feet above the sea. It appears that in one district of this island there are 7 cones, exhibiting no traces of cul-

* By the Hon. Henry Grey Bennet, M.P. Pres. Geological Soc.

ture, no appearance of vegetation; that the soil of the island is altogether volcanic; that in one valley there are 100 strata of lava; and that every rock and stratum, in a word the whole island, is the production of volcanic eruptions.

But our present object is with volcanoes, as being the cause of the ruin, and as forming anew, some of the constituent masses of the crust of the globe. Therefore, after some general and concise account of the nature of true volcanoes, we shall proceed to the consideration of the geological nature of one or two mountains, wherein those are situated of which we have the most authentic accounts, as of Vesuvius and Ætna; concluding our slight outline (for it is a slight outline alone that I shall be able to present) with such an account of the probable origin of volcanoes as the researches of the scientific afford.

Volcanoes have usually a conical shape, and are provided sometimes with one, sometimes with several mouths or craters.

In an active state, they occasionally eject smoke, vapour, flame, glowing and melted masses, and more rarely, water.

The occasional eruptions of large volcanoes are usually accompanied with earthquakes and lightning.

But when a volcano ejects only smoke, it is considered to be in a state of rest. This smoke is said to be composed of steam or watery vapour, the muriatic and sulphureous gasses; also of azote, carbonic acid, and hydrogen gas. If the smoke be black, it contains much carbonaceous matter; when grey or of a white colour, it is principally composed of aqueous vapour.

In a greater state of activity, glowing masses are

ejected. These do not follow at regular periods, except in one instance that will be noticed presently. They are generally accompanied by a noise proportioned in loudness to the magnitude of the stones that are projected, and the height to which they ascend. Ashes also are occasionally thrown out in prodigious quantities.

But the most striking phenomena exhibited by volcanoes, are the flowing streams of melted matter called lava, from their craters. These are usually preceded by earthquakes.

The instance just now mentioned as an exception to the rule that the eruptions of volcanoes are not periodical, is that of Stromboli, one of the Lipari islands.

According to Dolomieu the crater of Stromboli does not exceed fifty paces in diameter. This volcano is mentioned by Pliny; and it is said that from time immemorial, its eruptions have taken place about every 7 or 8 minutes. 'I saw it dart,' says Dolomieu, 'during the night, at regular intervals of 7 or 8 minutes, ignited stones, which rose to the height of more than 100 feet, forming radii a little diverging; but of which the greater part fell into the crater, while others rolled even to the sea. Each explosion was accompanied by a burst of red flame. The stones ejected are of a lively red, and sparkle, having the effect of artificial fire works. The approach of the eruption is not announced by any noise or dull murmur in the interior of the mountain.'

Vesuvius is a mountain of about 30 miles in circumference, and 3600 feet in height. The first recorded eruption is that of the year 79, which covered the towns of Pompeii and Herculaneum with a shower chiefly of sand and ashes of 80 feet in depth: but as late researches beneath this bed of ashes and even to the foundations of

the houses of Pompeii and Herculaneum, have proved that their streets were paved with volcanic matter, no doubt can be entertained that Vesuvius was a volcano at a much earlier period. Since the eruption just noticed as having happened in the year 79, thirty eruptions of Vesuvius, of different degrees of violence, have been recorded.

In 1538, a mountain principally of sand and ashes, 3 miles in circumference and $\frac{1}{4}$ of a mile in height, was thrown up in one night.

An eruption of great violence, but inferior in this respect to that just noticed, was particularly described by Sir William Hamilton. It occurred in 1767, and lasted at intervals several days and nights. Streams of lava flowed; and prodigious quantities of ashes ascended, which it is said fell in Manfredonia, 100 miles distant from Vesuvius, in two hours after they were projected. Vast masses of stone were likewise thrown out by this eruption, which was accompanied by earthquake and lightning; many of these masses were measured by Sir William Hamilton; the largest of them was 108 feet in circumference, and 17 in length, but there were several not much inferior in bulk.

A stream of lava issued after the eruption of 1784, one mile wide and about twelve feet deep.

Within in the ancient crater of Vesuvius, according to Menard de la Groze who visited the summit seven times, is situated a cone, which has been thrown up by the comparatively modern effects of the volcano, and on which are visible smaller cones formed by occasional eruptions, which now happen almost every year, instead of suffering a lapse of half a century between them as heretofore.

Three craters were opened on the sides of the mountain in the eruption of 1807.

Preceding and during the eruptions of Vesuvius, the water of the neighbouring wells sink considerably.

They are accompanied by explosions of great violence, and by a sensible smell of the muriatic and sulphuric acids.

The stones which are projected the highest are those which fall back into the crater; these rise about three times the height of the cone, that is about 500 feet, and occupy four, five, or six seconds in their fall. By the light of the sun these appeared of a blood red, and by night of a white heat.

He says that, with his handkerchief before his face, he got in front of a stream of lava which had been projected some time, but which was still marching very slowly along; that he found it impossible to make any impression on it with the point of his stick, even where it seemed in the softest state. No flame issued from the fissures of the lava, which was below still red hot, nor did he discover any smell of sulphur, or petroleum, or the muriatic acid, although he passed over the stream in various directions, and even almost as high as the cone; but he only perceived a vapour resembling common steam.

A particular account of volcanic eruptions would prove highly interesting, but our business with volcanoes is geological. I shall therefore content myself with saying in respect to the nature of the eruptions of Ætna, that the projected matters much resemble those of Vesuvius. Ætna is above 10,000 feet high, and is about 130 miles in circumference: it was noticed as a volcano by Diodorus Siculus, 450 years before the Christian era.

But there is so great a difference in the nature of the substances thrown out by some of the American volcanoes, that they merit particular notice. Several of these are situated in mountains more than 10,000 feet high, and that of Cotopaxi, which is the highest, is 18,880 feet above the sea. According to Humboldt, these volcanoes scarcely ever throw out lava, but chiefly slag, ashes, a substance resembling pumice, and vast quantities of water, with an earthy or slimy mass, which often contains vast numbers of fishes. Hence, in the accounts of the tremendous volcanic eruptions that have taken place in the province of Quito, we hear only of overflowings, or of bodies being buried in slimy mud; never of the burnings that characterize the eruptions of some other volcanoes. When the volcano of Carguairazo fell down, on the night of the 16th July, 1698, it overflowed a tract of country 16 or 18 square miles, with slimy mud. The number of human beings destroyed was so great, that the bodies were interred in heaps. During the great earthquake of the 4th February, 1797, 40,000 human beings were destroyed by the water and mud that issued from the mountains.

The substances ejected by pseudo volcanoes are, burnt clay, porcelain-jasper, earth-slag, columnar clay ironstone, and polishing slate.

Those ejected by true volcanoes are, granular limestone imbedding various minerals, most of them crystallized, and occasionally granite, mica-slate, greenstone, and sandstone; these substances have not undergone fusion, and frequently contain crystals of various substances unaltered; pumice, obsidian or volcanic glass, slime called volcanic tuff, sulphur, and muriate of ammonia, are in general in greater or less quantity, also the products of volcanic eruptions.

Of the origin of volcanoes we can only reason from the nature of the substances they present to us. Many have been of opinion that volcanic mountains are wholly the results of the matter and masses ejected during eruptions, and that the real seat of volcanoes is very deep in the earth. Of the depth at which they may be situated we know but little: but there seems no reason for believing that volcanic mountains in the general have been thrown up by the volcanoes that yet continue within them, or beneath their base.

Of the actual nature of Vesuvius as a mountain we know but little: we know that it often ejects calcareous matter, and that the country all around it is calcareous: but our information in regard to Ætna is more to the point. It has already been mentioned that on the sides of that mountain a bed of sea shells has been discovered 2400 feet above the sea. It is therefore incredible that its whole bulk, or even that its whole surface, should be of volcanic origin, since the ruins of a temple built before our era, still stand on its side, uncovered by volcanic matter: and from the nature of the masses composing the volcanic mountain which fell in America, geologists are perfectly assured that the mountain itself could not have resulted from volcanic eruptions.

It has already been noticed that no known volcano is seated in granite, and that granite is not to be seen near any volcano, except in very low situations. The same may be said of primitive rocks in general. One eruption of Ætna covered a space of 50 leagues in circumference, and 12 feet in thickness, with calcareous sand; and calcareous earth, though it forms a very large proportion of secondary, enters very sparingly into the composition of primitive rocks: so that some geologists

are not inclined to believe that volcanoes are very deeply seated in the earth.

Where fire exists we naturally believe the existence of combustibles. The known combustion of sulphur and iron filings induced many to suppose that volcanoes originate from the decomposition of vast deposites of pyrites, which are composed of iron and sulphur: but no spontaneous inflammation of pyrites has ever been observed.

Werner has given his attention to the subject of the probable origin of volcanoes; and knowing that coal has ignited spontaneously, and that there are vast beds of this substance, of which that at Liege in France, 90 feet thick, and 2 beds in Bohemia, one of which has been worked 90 feet deep, and the other much deeper without reaching the bottom, are instances; he is inclined to suppose that to vast deposites of coal may be attributed the origin of volcanoes. The consequence of the spontaneous combustion of immense beds of coal would be the melting of the stony beds that rest upon it. But the question arises, whence the power of raising vast masses, and of ejecting them, together with prodigious showers of sand? The answer follows; the expansion of aqueous vapour, or steam; and that water plentifully flows from many volcanoes, particularly those of America, we have already quoted sufficient evidence.

Humboldt, who it must be acknowledged has had ample opportunity for observing the phenomena of volcanoes, is of opinion that certain of them are very deeply seated in the earth. He says it is a remarkable fact that the volcanoes of Mexico are ranged in a line from east to west, forming a parallel of great elevation. In reflecting on this fact, and comparing it with his observa-

tions upon certain phenomena attending Vesuvius, he is tempted to suppose that the subterraneous fire has pierced through an enormous crevice, which exists in the bowels of the earth, between the latitudes of 18°. 59. and 19°. 12′. and stretches from the Pacific to the Atlantic ocean.

From the great differences in the theories of these naturalists, we are necessarily led to the conclusion, that as yet we have no sufficient data to enable us reasonably to account for the origin of volcanoes.

OF THE DELUGE.

The traditions recorded by many persons and nations perfectly agree with the writings of Moses, and with the researches of geologists, in regard to the actual state of the surface of the globe, in this, that it has suffered a great catastrophe by water. It is alluded to by Berosus in the time of Alexander; by Plato; by the Hindus; who, according to Sir William Jones, mention it in one of their sacred books, or vedas, nearly in the same terms, and refer it to nearly the same period as Moses; and in the records of the Chinese philosopher Confucius, there is an allusion in the following terms; ‘ Having raised himself to heaven, Yao bathed the feet even of the highest mountains, covered the less elevated hills, and rendered the plains impassable :’ allusions to the deluge are also said to be involved in the astronomical calculations of the Chaldeans. It is remarked by Cuvier that *mere chance* could not give so striking a resemblance between the traditions of the Assyrians, the Hindus and

the Chinese; who moreover attribute the origin of their respective monarchies to the same period of about 4000 years back. The ideas of these three nations, who have so few features of resemblance, or rather, who are so entirely dissimilar in language, religion and laws, could not have so exactly agreed on this point, if it had not been founded in truth. Other and remarkable traditional evidence may be adduced.

Acosta, in his history of the Indies, says that the Mexicans make particular mention of a deluge by which all men were drowned; and Dr. Watson, in one of his sermons, records a reply given by an inhabitant of Otaheite to one of our circumnavigators, to a question regarding their origin: that 'a long time ago, the earth was dragged through the sea; and their island, being broken off, was preserved.'

If it be true, as stated by Don Ulloa, that during his travels in Peru he found shells on a mountain more than 14,000 feet above the level of the sea, it affords presumptive evidence that the sea must have attained that elevation; which is nearly equal to two-thirds the height of the most elevated points of land: and if it arose to so great a height, there seems no reason for assuming that as the limit; we may reasonably thence infer that it covered the tops of the highest mountains.

There are however many circumstances relating to the lower parts of the earth that afford interesting evidence of the universal agency of water. The compact argillaceous substance called shale, which lies over the independent coal formation, is often found to enclose vegetable remains; and it is said to exhibit, near Coalbrookedale, the impressions of gigantic ferns and reeds peculiar to the American continent. Deposites of ma-

rine plants and animals have been found in the interior of the European and Asiatic continents, frequently in considerable abundance. In Corsica are found the remains of an animal exclusively belonging to Siberia. In the year 1771 the carcase of a rhinoceros, an inhabitant of the torrid zone, was found on the banks of the Vilhoui. The bones of the mammoth, which is a species of the elephant, are found in three of the four quarters of the globe; and those both of the African and Asiatic elephant, have been found in many places in England: they occur likewise in Italy, France, Germany and Sweden. It is worthy of remark, that, although in the two cited instances, the carcases of the animals occurred nearly whole, entire skeletons are seldom found, but mostly separate bones, widely dispersed: and it is said that between the countries now inhabited by these animals, and some of those in which their bones have been discovered, there are chains of mountains exceeding 9000 feet in elevation.

All these circumstances seem to speak a language so perfectly intelligible that it cannot be misunderstood; that since the creation of animals the world has suffered by universal inundation; that 'all the fountains of the great deep were broken up, and the windows of heaven were opened.'

The manner in which this deluge was accomplished, is a problem that has long occupied the imaginations of philosophers and naturalists.

The question is this: since the tops of the highest mountains, which are about four miles above the present level of the sea, were covered with water; whence could be derived a sufficient quantity to surround, to the depth of four miles, a globe 25,000 miles in circumference.

It is evident that in order to accomplish this, the rain of forty days and nights was not sufficient; for the context says that ‘all the fountains of the great deep were broken up.’

What precisely is meant by the *great deep* and where it was situated, still continues to be problematical. Attempts at its explanation have caused the fabrication of at least fifty theories of the earth, not one of which is satisfactory.

Some of these theories were briefly recounted on a former evening, as being more or less connected with the creation of the world.

Burnet imagined that before the deluge, the earth was a mere crust, containing a vast abyss of waters; which issuing, deluged the earth, forming mountains of the broken crust.

Whiston supposed the deluge to have been occasioned by a comet. But a bare recital of hypotheses so gratuitous would scarcely be amusing; for in the general, there is so little agreement between them and the known phenomena of nature, as resulting from *those laws which in point of fact constitute nature*, that they are no longer deemed worthy of a place in a rational mind. Other theorists, however, bent upon a more reasonable philosophy, have looked into nature for a solution of this interesting question.

Kirwan has assumed that, in addition to the rain of forty days and nights, a prodigious rising took place in the waters of the great Southern Ocean, which, he sets out with saying, is the greatest collection of waters on the face of the globe; that this ocean was the great deep mentioned by Moses; and he supposes that Noah resided on its borders, for otherwise he could not have

seen that the great abyss was opened. He conceives that these waters were impelled northwards, with resistless impetuosity, against the continent which at that time probably united Asia with America; tearing up and sweeping away the whole of that immense tract, with the exception of those islands which still remain.

Here then is supposed a suspension of some of the laws of nature, or how could so vast a body of waters have arisen from its natural level, and have torn up and swept away a whole connecting continent, by what Kirwan terms its resistless impetuosity. I do not propose to follow him through all the ramifications of his theory, but it may be not amiss to notice the apparent impossibility that the ark, or the little world within it, could have sustained the horrible shocks that must have been given to it by surges equal in power and frequent enough in repetition, to cause the destruction of a continent.

Others have resorted to another theory. It is known that there is at all times a passage of electric matter into the earth, or from the earth into the atmosphere; and it is presumed that the electric fluid contained in the atmosphere, is the agent which suspends *therein*, the water which rises from the earth in vapour.

Now they suppose that natural causes were so influenced for the sake of producing the deluge, as that the air being divested of the electric fluid, universal and amazing torrents of rain fell during forty days and nights. And it is further supposed that as the earth contained a double portion of electric fluid, which experiment has proved to possess the power of raising water upon and above the earth, that the waters contained in its fissures and caverns, and even whole oceans, were thereby raised so far above their natural elevations, as to cover the tops of the highest mountains.

Thus has the sagacity of man (according to the present extent of his knowledge) been brought into action, in the endeavour to account for this wonderful phenomenon; and we have seen that even those who have attempted to explain it, in some sort through the agency of natural causes, have been compelled to call in aid of their theories, the miraculous intervention of the Great Author of Nature.

OF THE INTERNAL STRUCTURE OF THE EARTH, AND OF THE PROBABLE AGENT EMPLOYED IN PRODUCING THAT STRUCTURE.

The evidence produced on former evenings has satisfactorily proved, as I trust, that the researches of geologists have warranted them in making three grand features in the division of the rocks or masses which compose the crust of the globe.

Primitive Rocks:

Consist only of crystalline deposites;
Contain no organic remains;
Are found below all other rocks;
Rise from the base through all other rocks, and form the summits of lofty mountains.

Transition and Flœtz: or Secondary Rocks:

Consist partly of Crystalline, partly of mechanical deposites;
Contain organic remains of shells; some of them not now found in the seas;
Are never found under primitive rocks.

ALLUVIAL DEPOSITES:

Consist of mechanical deposites;
Result from the ruin of rocks;
Contain the shells of fish now found in the ocean, and the bones of large land animals.
Are found above all the other rocks.

Geologists, almost universally, have agreed upon the nature and stiucture of the two latter descriptions of rocks, and even upon the manner in which they were deposited. For as almost all the rocks denominated secondary, and those called alluvial, contain the shells of fish which once lived in the sea; all agree that these rocks must have been formed since those fish lived; and that, generally speaking, they were deposited by the sea.

But in the estimation of some, primitive rocks, which are so termed chiefly because they contain no organic remains, do not owe their origin to the same cause. For though all coincide in the belief that the earth, to a certain depth, has once been in a fluid state, of which its spheroidal figure is considered to be a proof, yet opinions as to the nature of that fluid are most completely at variance: inasmuch as one party considers it to have been caused by the agency of *fire*, and the other by that of *water*.

These two parties are termed *volcanists* and *neptunists;* or more familiarly by geologists, *Huttonians* and *Wernerians;* because the late Dr. Hutton of Edinburgh was the great champion for the agency of fire, and because Werner, now residing in Germany, espouses the opposite theory.

Dr. Hutton seemed to consider that the great question we have to decide, is, *how our vast continents have*

been raised so high above the level of the sea. Arguing from certain chemical facts, which it is not my province to explain, Dr. Hutton thought himself justified in supposing that the older rocks, as granite and the rest, were formed from a mass in a state of fusion by fire: that owing to the intensity of this fire, and the expansion consequent to that intensity, in the central parts of the earth, all those rocks which are termed primitive, on which all others rest, and which form as it were the rough frame-work of the earth, *were raised up, forming continents and islands.* He moreover supposed that in cooling, these vast masses suffered contractions, producing rents and fissures in them; which afterwards were filled from the central fire, with metallic and other substances; constituting what are now known by the name of mineral veins.

Contemplating the causes of destruction perpetually operating, as volcanoes, exposure to rains and air, and sea-floods; Dr. Hutton also imagined that these, by the destruction they cause, and the quantity of ruin they carry from the land, are perpetually laying, in the unfathomable regions of the sea, the foundations of new continents; which, gradually rising, will in turn destroy those now existing.

Dr. Hutton does not suppose the earth, as it now is, to have been an original creation, but that it has resulted from the ruin of other and former worlds; of which he emphatically says, 'we can find no vestige of a beginning, no prospect of an end.'

Werner, on the contrary, does not seem to consider that the great question we have to decide is, how our vast continents have been *raised* so high above the sea.

He considers primitive rocks to be precisely in the

situation in which they were first deposited; and as these rocks are all crystalline, or composed of vast aggregations of crystals, that the substances of which these crystals consist, being held in solution in a body of water, greater in elevation than the summits of our highest mountains, followed the laws of affinity, and were deposited, forming those masses termed primitive rocks.

That these rocks, during their consolidation, split, forming rents and fissures; that these fissures were filled from the ocean with mineral substances, and are what we now term mineral veins.

Such are the outlines of the two theories which now divide the opinions of geologists. Upon their comparative merits, it will not perhaps become me to say much. Yet although no opportunity has hitherto occurred, or perhaps ever will occur, for my examination of geological facts on a large scale, I am unwilling to leave the subject without expressing some opinion.

It may be true that the chemical facts on which they rely who espouse the theory of the agency of fire, may not have been altogether controverted; and that these facts may apply, by possibility, to the formation of certain rocks: but arguing generally, from what is known of the nature of fire and of fuel, from what may be learned by the examination of hand specimens, and from the results obtained by the application of chemical agency to their component parts; I find it impossible not to give a preference to that theory which ascribes the formation of primitive rocks to the agency of water. It appears to me, that an opposition to the agency of fire may reasonably be supported by certain phenomena presented to us by the component substances of granite and

gneiss, the two oldest of the primitive rocks, which are for the most part compounded of regular crystals of quartz, felspar, and mica, irregularly disposed in so far as regards each other.

If we could once arrive at any certainty that a single crystal of either of these substances had, in any case, been formed through the agency of either fire or water, it would seem to form reasonable ground for attributing the whole to the same agency. If, for instance, we could shew that a crystal of quartz had been formed in water, it would go near to determine the question; because as the crystals of quartz, felspar, and mica, aggregately forming granite, are irregularly disposed with regard to each other; and as the crystals of quartz sometimes enclose lesser crystals of felspar or of mica, it seems clear that the same agency must be referable for the production of the whole.

Now it has been already quoted that professor Seigling discovered some crystals of quartz that were deposited from an aqueous solution in which silex predominated, termed the *liquor of flints*, and which had accidentally been left eight years unobserved: these crystals were hard enough to give fire by the steel. It is asserted that Bergman also obtained crystals of the same substance from an aqueous solution containing silex.*

These facts may not be deemed conclusive of the question; but we have, as it seems to me, strong corroborative evidence in addition.

Crystals of quartz are by no means uncommon, in which are enclosed both *water* and *air*. I possess two or three such specimens; as well as another enclosing

* See Note page 100; see also Nicholson's Journal, vol. i. page 217, of quarto edition.

together with *water* and *air*, a minute portion of a dark substance that seems to be *bitumen*; which, turn the crystal any way, always presents itself in the air, and swimming on the water.

Now if in the production of these crystals, fire had been the agent, would not the water have passed off in the form of vapour, and the bitumen have been consumed? It seems impossible to suppose these crystals to have been formed by any other agency than that of water.

Other facts are worth observing. If a crystal of quartz be exposed to a red heat, it loses its brilliancy, together with about three parts in the hundred of its weight, and is no longer transparent. This loss, it should seem can be no other than the loss of water taken up during crystallization. The same holds in part with regard to felspar; which, though it never is transparent, loses from two to forty parts in the hundred of its weight, when exposed to the same heat.

Facts so pointed and important in regard to two of the three substances composing the oldest of the primitive rocks, seem to furnish strong evidence, that in the reducing into their present state the substances composing the great masses which form the crust of the globe, water was the agent.

We have now completed the object we had in view, in dedicating five evenings to the investigation of simple and compound mineral bodies; namely, *an outline of the great masses composing the crust of the globe; of their arrangement; and of their component substances.*

In this view I have as much as possible studied brevity. It may be well imagined that there are many

facts, considerations and enquiries, of which nothing has been said; facts in regard to the relative nature and positions of compound mineral bodies and masses; considerations and inquiries into which those facts would necessarily lead.

Enough however, I trust, has been said to show that geologists have truth for their object. That faculty of genius which consists in invention no longer presides; the theories which attributed the origin of the globe to a portion of the sun struck off by a comet, and fifty others equally absurd, are gone by and neglected. Patient and profound investigation has taken their place; producing research nearly to the summits of our most elevated mountains, and to the greatest depths to which the miner can descend.

But since it is computed that all our researches do not extend further into the earth, than, by comparison, the thickness of the paper which covers a globe of three feet in diameter, is to that globe; it will follow that we do not possess any knowledge of what the central parts of the earth are actually constituted.

We have however the most indubitable evidence that the crust of the globe has been subjected to revolutions, both partial and general. We are assured by the numerous facts that have been quoted, and by far more numerous which yet remain, that the sea must have changed both its *place* and its *height*. Proofs have been adduced that animal life has repeatedly and largely fallen the victim to these terrible events. There seems reason to conclude that some animals have been destroyed by sudden inundations; that others have been laid dry in consequence of the bottom of the sea being suddenly elevated; and that these calamities have caused great changes in the outer crust of the globe. It seems also

clear, that since these first and greater commotions, those which followed, uniformly acted at a *less depth* and *less generally*. We have seen that the researches of geologists have ascertained that *of those animated beings, of which the remains are enclosed in those rocks which immediately rest upon primitive rocks, the races have become extinct; that the newer rocks contain the remains of animals more nearly approaching to, but not absolutely of the same species as, those inhabiting our present seas; but that the newest contain only the remains of such animals as now exist in the seas, together with the bones of large land and amphibious animals.*

Every part of the globe distinctly bears the impress of these great and terrible events. The appearances of change and ruin are stamped on every feature. Change and ruin *by which not a particle of the creation has been lost*, but which have been *repeated* and are *distinctly marked by the genera and species of the organic remains they enclose.*

Thus, those fossils and petrifactions which heretofore were carefully collected as curiosities, now possess a value greater than as *mere* curiosities. They are to the globe what coins are to the history of its inhabitants; they denote the period of revolution; they ascertain at least comparative dates.

If the inquiry should arise, What benefit has resulted from ruin so extensive and so general? the answer is obvious; *soil and fertility*. If for a moment we imagine a world composed only of those rocks which we call primitive, which bear no marks of ruin, enclose no organic remains; we know from the nature of their component substances, that their exposure to the action of the elements during very many ages, would scarcely so separate and disintegrate them, as to produce a soil capable of

any considerable vegetation; in other words, would fit the earth to receive and to maintain an extensive and almost universal population. A large and fertile part of England, is composed of the ruin of rocks to a considerable depth; and this greatly obtains in all the most level and most fertile countries. Are we not then in degree justified in assuming that this great ruin was designed to fit and prepare the earth for the support of the numerous animal tribes that inhabit it; most especially for MAN; who, doubtless from his superior intellectual endowments, has emphatically been termed 'the Lord of the Creation.'

But our inquiries into utility need not stop here. All our researches have evinced such unquestionable proofs of design and contrivance, that it is impossible not to see them; and if we see them, it is or ought to be equally impossible not to ascribe them to the great Artificer of the universe. This indeed is the reasonable end and aim of all our inquiries, and all our philosophizing.

Without *mountains*, what in all probability would be the earth? A swamp or a sandy desert; and the atmosphere a receptacle of noisome and pestilential exhalation. As conductors of the electric fluid, mountains contribute to the production of rain, which fertilizes the earth and purifies the atmosphere. They are the principal repositories of metallic ores. Their benefits, therefore, are great and extensive.

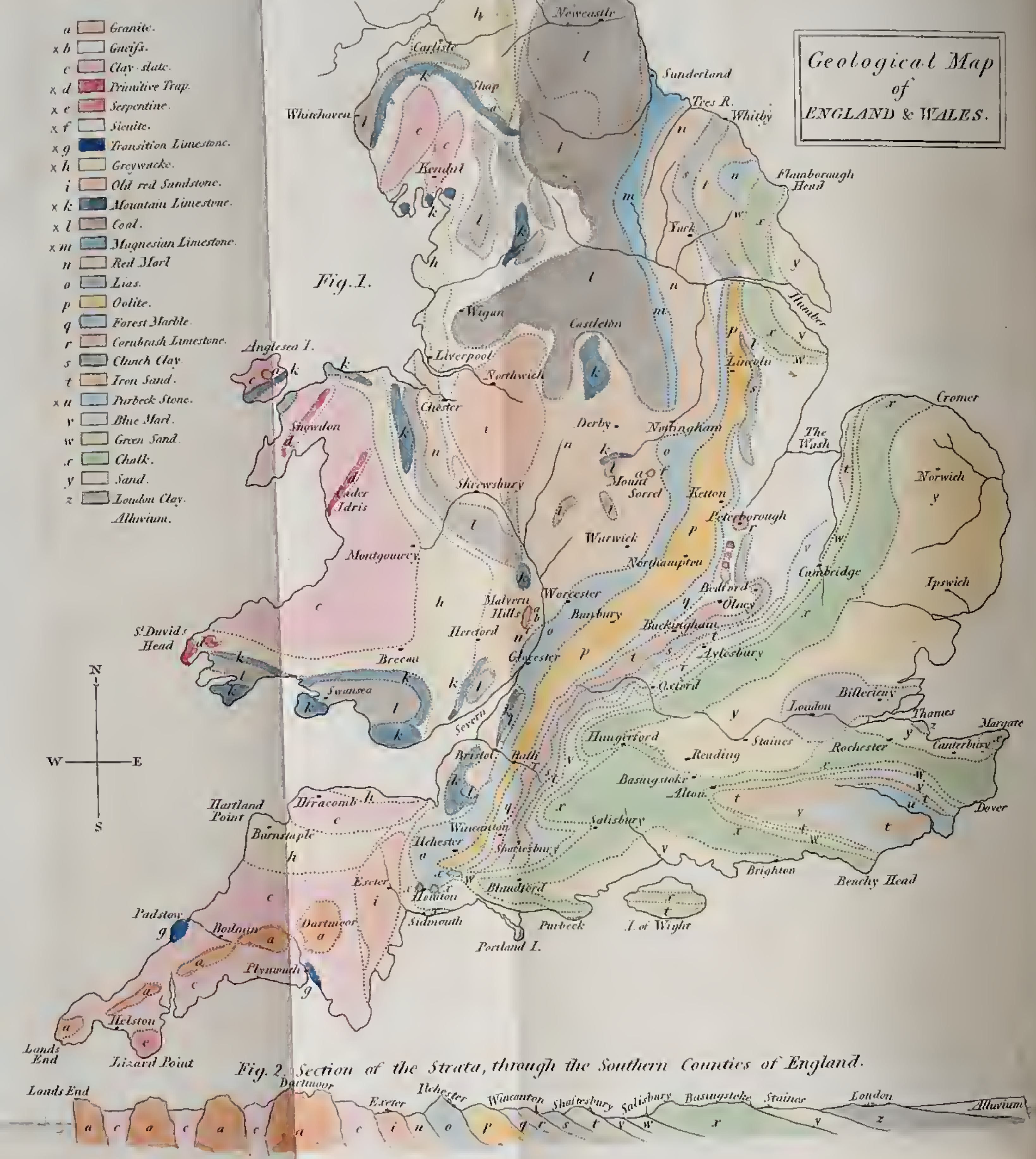
Metallic ores and mineral substances, it may be remarked, either in the simple or compound state, are found in quantity *admirably apportioned to their utility*; and, in the same proportion, with whatsoever they may be combined, they are generally most readily and easily freed from those substances with which they are compounded. Is it possible for one moment to doubt whe-

ther all this *exhibits design and contrivance for the benefit of Man?*

But further; is not design manifest in regard to the depositions of salt and of coal, so essential to man? Suppose these to have taken place between the earlier rocks, or in the masses of primitive mountains, or any where except where we find them; that is, just beneath the surface: they would in that case have been nearly lost to man. Can we appreciate their present benefits? Can we doubt that there was design in placing them where we find them?

But in speaking of soil and fertility as the consequence of the decay and ruin every where to be observed, I omitted one important consideration; namely, the decay of vegetables, which so essentially contributes to fertility, as principally composing what we call *mould.* But there is one exception to the general rule in regard to the decay of vegetable matter, not sufficiently noticed, as being an exception in the favour of Man; but which demands a thought. The leaf, after it has fallen, enriches our soil; the gardener esteems it an excellent manure; but the tree that bore the leaf, when deprived of life, decays not until after a long period of time; not until it has long been in the service of Man. Without wood, how should we be able to accomplish the many purposes to which it is applied? Where could we find a substitute?

This, I grant, is a digression; but it is almost the only one I have allowed myself. I shall perhaps be excused, when it is considered, that it is adding another proof, in itself rather too obvious to attract much notice, to the many already adduced, *that design and contrivance are every where manifest, and in every thing intended for the advantage of Man.*


Geological Map of ENGLAND & WALES.
a Granite.
x b Gneifs.
c Clay slate.
x d Primitive Trap.
x e Serpentine.
x f Sienite.
x g Transition Limestone.
x h Greywacke.
i Old red Sandstone.
x k Mountain Limestone.
x l Coal.
x m Magnesian Limestone.
n Red Marl.
o Lias.
p Oolite.
q Forest Marble.
r Cornbrash Limestone.
s Clunch Clay.
t Iron Sand.
x u Purbeck Stone.
v Blue Marl.
w Green Sand.
x Chalk.
y Sand.
z London Clay.
Alluvium.
Fig. 1.
N
W
E
S
Newcastle
Carlisle
Sunderland
Tres R.
Whitby
Whitehaven
Shap
Kendal
Flamborough Head
York
Humber
Wigan
Castleton
Liverpool
Northwich
Anglesea I.
Lincoln
Chester
Snowdon
Derby
Nottingham
The Wash
Cromer
Mount Sorrel
Ketton
Norwich
Shrewsbury
Cader Idris
Peterborough
Warwick
Montgomery
Northampton
Cambridge
Ipswich
Worcester
Bedford
Olney
Malvern Hills
Banbury
Buckingham
St. Davids Head
Hereford
Aylesbury
Brecon
Glocester
Oxford
Billericay
Swansea
London
Thames
Margate
Severn
Staines
Hungerford
Rochester
Canterbury
Bristol
Bath
Reading
Basingstoke
Alton
Dover
Hartland Point
Ilfracombe
Salisbury
Barnstaple
Wincanton
Ilchester
Shaftesbury
Brighton
Beachy Head
Exeter
Honiton
Blandford
Padstow
Bodmin
Dartmoor
Sidmouth
Purbeck
I. of Wight
Portland I.
Plymouth
Helston
Lands End
Lizard Point
Fig. 2. Section of the Strata, through the Southern Counties of England.
Lands End
Dartmoor
Exeter
Ilchester
Wincanton
Shaftesbury
Salisbury
Basingstoke
Staines
London
Alluvium

OUTLINE OF THE GEOLOGY

OF

ENGLAND AND WALES.

§ I. *Of England.*

It has frequently been said that the traveller who visits other countries should first become acquainted with his own. The same advice might be given to the geological student, if indeed it were possible that he should need any stimulus to become acquainted with the geology of his own country. Though the science is yet in its infancy in this kingdom, it is an infancy of great promise; a taste for it is daily gaining ground, and the constant researches of many able geologists are continually offering fresh accession of important information respecting Britain.

The Transactions of the Geological and Wernerian Societies include many highly interesting and valuable communications on this subject, as well as some of the periodical journals; and within the last few months a very important addition to our information has been given to the public in the form of a "Map of the Strata of England, Wales, and Scotland, by W. Smith," who first noticed that *certain fossils are peculiar to*, and are

only found in, particular strata; and first ascertained the *constancy in the order of super-position,* and *the continuity in the strata of this island.**

When it is considered that this map is the production of one man, it is impossible not to view it with admiration, as the result of a combination of talent and industry rarely associated in the same person. The author of it, during at least twenty years, has visited and re-visited almost every corner of England, with his attention always alive to objects which at length possess attractions for very many of his countrymen.

This Map is extremely interesting, even though we should be compellêd to suppose that it is not every where equally accurate in its detail. Viewing it, however, as it has already been termed, as an important addition to our geological information respecting Britain, I feel anxious to turn the attention of the student to it: but as the large and expensive scale on which it is done, and which is essential to the accurate expression of the details which it includes, may forbid its falling under the notice of every one, I proceed to a few short and general remarks on the Geology of England and Wales, taking this map, by permission of the author, as the basis; conceiving that it will prove advantageous to the beginner to learn that *England is a regularly stratified country;* that *the order of its strata is never inverted;* and that *exactly similar fossils are found in distant parts of the same stratum,* wheresoever it traverses the island.* In whatever part of it the young geologist may travel, it must be desirable to him to know something of the nature of the rock that supports him, and even of the pro-

* Geolog. Trans. vol. i. p. 325. † Ibid.

babilities in regard to the succession of the strata far beneath his feet.

Regular, numerous and varied as are the strata of England, it is nevertheless possible that a traveller whose attention has in no degree been turned to geological objects and pursuits, should pass over a long tract of country consisting of very different rocks, without heeding their difference. The sod is so continuous in many districts, and the alluvial matter so deep, that superficial observers stand little chance of remarking a change in the nature of the sub-stratum. As the artist views every object that presents itself in a manner which bespeaks him mindful of his art; so the geologist, as he passes along, regards every opening beneath the surface, every quarry, as yielding him some information in his favorite pursuit; and the experienced geologist, viewing nature on a broader scale, can with a sort of instinctive readiness discern, even at a considerable distance, any remarkable change of the sub-stratum, by remarking the form of the outline of surrounding elevations.

It is doubtless understood that strata and formations vary greatly in dimension as well as regularity. The same stratum in one place may be some miles in extent at the surface, or rather, immediately beneath the soil; becoming, perhaps at no great distance, diminished and narrowed to a very small compass, or even entirely lost; so that the two rocks which before bounded it one on each side, now immediately repose the one upon the other. Again perhaps it re-appears and again is lost. The appearance of a stratum at the surface is termed its *outgoing*, *bassetting*, or *cropping out*. Its direction beneath the surface is termed its *dip:* when a stratum, or rock, is in its natural position, it is said to be *in situ*.

The annexed Map (Plate 5,) affords a rough and superficial view of the strata of England and Wales. It is not intended to be accurate in its detail, but it may suffice to give a general outline of the actual position of the various strata in regard to each other.

By this Map, slight as is the view which it affords, it will be seen that the western side of the kingdom is of the oldest formation, consisting chiefly of primitive rocks; that the middle district, in which the strata more evidently run, generally speaking, north-east and south-west, consist of the older secondary rocks; and that the eastern parts, consisting chiefly of chalk and of strata reposing on it, are of the new secondary; upon the newest of these reposes alluvial matter.

The greatest elevations are presented by some of the older rocks in Wales and the North of England. The rugged outline, and occasionally the precipitous summits of these, are to the observer indications of their being of the earliest formation; while the smooth and rounded undulation of the chalk bespeaks its newer formation, even though not a speck should appear, divested of herbage. The outline is commonly a better means of judging of the comparative ages of rocks than their elevations. The granite range of Cornwall no where attains so great a height as many mountains in Wales and the Northern parts of England, though it is of earlier formation. The granite of the West of England no where exceeds 1360 feet above the sea; while Snowdon, whose rugged peaks consist chiefly of rocks of the trap formation, attains the height of 3456 feet.

All parts of England are not however equally well known; in other words, all have not been in the same degree explored by Geologists: but we are acquainted

with much that is interesting in respect of almost every district. The Southern parts of England are perhaps the best understood. It is worthy of note that Dr. Berger, a geologist of acknowledged merit, and of the Wernerian school, who has visited many, if not most parts of the European continent, says, 'If we take a comprehensive view of the *Southern counties of England, from the east of Kent to the Land's End*, we may safely assert that there are few countries which, within such limits, can boast of *so varied and regular a succession of rocks; from those which are reckoned by most geologists to be of the latest formation, to those which are of the oldest.*'*

This acknowledgment on the part of a Geologist of so much experience and merit as Dr. Berger, is highly interesting to us all. Which of us, after being made acquainted with this fact, but will exert all his faculties for observation whenever avocation or pleasure shall induce him to travel over so inviting a country? Meantime it may prove advantageous to the beginner to become acquainted at home, not only with the nature of the various strata over which he would pass in the district approaching to that pointed out by Dr. Berger, but also the manner in which those strata repose on each other.

Enough has already been said on the subject of strata and stratified countries to shew, that the research and experience of Geologists every where, coincide in establishing the fact, that the oldest rocks rise above and pass away beneath those which are newer; and that, as the latter repose on the former, they of course take the same direction. If therefore we again revert to the fact that the western side of England and Wales consists

* Geolog. Trans. vol. i. p. 267.

of the oldest rocks, and if also we take into consideration that the chains of primitive mountains occurring in Wales and in Cornwall, take their course north-east and south-west, we shall decide that their *dip* must be on the south-east, and consequently that all the numerous succeeding strata dip, generally speaking, in the same direction. This proves to be the fact; and it has been observed that the strata make a great angle of inclination in proceeding westward.

The annexed sketch (pl. 5. fig. 2.) will therefore represent a section of the country over which a traveller would pass from the Land's End in Cornwall to beyond London on the east. It also shews the general dip of each stratum; observing the interesting fact, that the dip of each becomes more nearly flat as we recede from the granite; and therefore more nearly assumes that direction which determined Werner to give to the newer secondary rocks the term of Flœtz, or Flat Rocks.

The order in which these rocks succeed each other, and their general direction, is all that is here intended to be pointed out. The details respecting them, comprehending an account of their precise dip,—the nature and number of their beds, which in some formations are very numerous,—their occasional intermixture,—the places at which they are lost, and again reappear,—the veins which traverse them,—would at least require a volume. This detail therefore is altogether inconsistent with our object.

The annexed Map might alone serve to convey a general outline of the Geology of England and Wales; on which the section will tend to throw some additional light, especially on that of the Southern counties of England. By comparing the section with the Map, and

with the little index to them which is placed in the upper part of the plate on the left, it will become obvious that several rocks occur in England *which are not found in that part of it, through which our line of section runs.* The rocks are placed in the index *in the order of their comparative ages*, according to the present state of our knowledge, beginning with the oldest; and those rocks which are not found in the section have a cross ╳ placed before the letter, which refers to the place of the outgoing of each rock upon the map; thus gneiss, primitive trap, serpentine, sienite, transition limestone, greywacké, mountain limestone, coal, magnesian limestone, and the purbeck stone, are not seen in the section: nevertheless these rocks occur in England in situations which do not militate against the commonly received opinions of *their respective order as to age and formation.*

But in addition to the information which the map and section convey, it may perhaps prove interesting briefly to notice a few prominent facts relative individually to the rocks forming the series of the strata of England. And, in order to render these very brief notices the more clear, I shall proceed first to give some account of *the strata which appear in the section*, and afterwards of those which *are not seen in it*, as above mentioned.

It is however proper first to remark, that *in or between many of the strata, there are occasional intervening beds or deposites of substances which are not noticed; these belong to that detail which is not within the limits of our present object.*

The earlier rocks belonging to our own country, are not so well understood as those of posterior dates. They

have been less thoroughly examined; and as far as they have been explored, their characters are less decidedly marked. It is by some considered that 'the whole of England displays evident marks of its stratification having suffered considerable disturbance from some prodigious and mysterious power.' By this power all the known strata, to the greatest depths they have been explored, have been more or less broken and displaced, so that 'great difficulties and confusion frequently arise in examining the superior strata.'*

GRANITE.

a. Plate 5, fig. 1 & 2.

I am not aware that this rock, which is considered to be the oldest of the primitive class, is to be seen in the northern counties, except that it rises at Shap, a few miles south of Penrith in Cumberland, forming a ridge of no considerable magnitude or elevation. A few miles north of Leicester, near the center of England, it rises forming a part of the small elevation called Mount Sorrel, where it is associated with rocks of the trap formation, and with schistose rocks of various descriptions.

Granite is again seen in the Malvern hills, which are about 9 miles in length, 1444 feet high, and run north and south near the borders of Herefordshire and Worcestershire.

The granite of these hills is unstratified, and is so greatly decomposed as scarcely to be recognized. On their eastern side it is associated with sienite. Gneiss

* Geolog. Trans. vol. i. p. 236.

reposes on its northern side. Granite chiefly appears in the west of England. The mountain chain of that country, *like all primitive ranges*, runs north-east and south-west; it extends about 120 miles from the center of Devonshire to the extremity of Cornwall, presenting a regularity in composition rarely found in great chains.* Its central and highest part is of granite, of which the summit of the hill called Brown Willy near Bodmin is the most elevated point, being 1358 feet above the level of the sea. According to Dr. Berger, the rock which reposes on the granite both on the northern and southern sides is graywacké; this rock is the killas of the Cornish miner, and is by most if not all geologists, with the foregoing exception, considered to be argillaceous schistus. It accompanies the granite on the southern side about 40 miles continuously, from the Hamoaze to the river Hel: the western extremity of Cornwall consists principally of granite. It has already been said, in treating of this rock generally, that there are considered to be two or three formations of it. The granite of Cornwall is not large grained; and therefore is not by some geologists esteemed to be of the earliest formation.

GNEISS.

This rock, which succeeds granite in respect of age, does not appear in the section, plate 5, fig. 2. For some account of it see page 209.

MICACEOUS SCHISTUS. See page 209.

* Geol. Trans. vol. 1.

ARGILLACEOUS SCHISTUS. CLAY SLATE.

c. Plate 5, fig. 1 & 2.

In the annexed section, argillaceous schistus reposes on granite, which it has already been said is flanked by the same rock both on the north and south for about 40 miles in Cornwall. It also occurs in many places reposing on the granite, and appearing to interrupt its continuity. At the foot of some of the hills forming the granite chain, the miner has alternately passed through granite and argillaceous schistus; but whether this has been owing to the alternation of these two rocks, or to the occasional cavities of the former being filled by depositions of the latter, has not been ascertained. A large portion of Wales is constituted of this rock; though not always precisely of the same kind (for there are many varieties of it), as that found in Cornwall. A slight view of the geological nature of Wales will hereafter succeed. Argillaceous schistus prevails considerably in the north of England, constituting many of the more considerable elevations in Cumberland and Westmoreland. Skidaw consists of it, as well as many other mountainous elevations in its neighbourhood. The plumbago of Borrodale is found in a mountain chiefly if not wholly consisting of argillaceous schistus. Near Tavistock in Devonshire it rises to the height of 1129 feet above the sea. Dunkerry Beacon, a mountain in Exmoor in Devonshire, rises near the junction of the clay slate and graywacké, to the height of 1664 feet. Skidaw and Helvellyn in the north of England, which consist of clay slate, rise, the latter to the height of 3324, and the former to that of 3530 feet.

The rocks which occur in England and Wales, next in respect of age to clay slate, are

PRIMITIVE TRAP,
SERPENTINE,
SIENITE,
TRANSITION LIMESTONE,
GREYWACKE;

but as these do not appear in the section, fig. 2, plate 5, no further notice of them will be taken here, than to say that some account of them appears pages 209, 210, and 211.

OLD RED SANDSTONE.

i. Plate 5, fig. 1 & 2.

This rock, in the west of England, reposes on argillaceous schistus, and continues for some miles on the road from Exeter to Ivy bridge; it is one of those rocks, whose characters differ very much from accidental circumstance; and it is frequently difficult, if not impossible in some instances, to determine on the precise formation of sandstones, even when seen *in situ*, which is the most favorable situation in which they can be observed. It has not been ascertained that this sandstone reaches from the place of section, uninterruptedly to some of the northern counties of England; but it is certain that a rock which in many places has some of its characteristics prevails from that place as far north as Liverpool. For the most part, however its characters are doubtful; but in a large portion of Cheshire and the northern half of Shropshire, the country consists of a rock which is judged to be the old red sandstone. In some places the loose sand on its surface contains rolled stones of quartz,

granite, greenstone, and porphyry, which also occur dispersed over its surface, though they are rarely imbedded in the rock. In some places it is covered by a slaty sandstone passing into marle, and containing shells.* There are no sandstone hills in Shropshire which rise higher than 400 feet. In the southern extremity of that county, it rests on elevated strata of graywacké. In general however it does not attain elevations which can be characterized better than by the term gentle hills.

The next in order of formation to the old red sandstone, are

MOUNTAIN LIMESTONE,
COAL,
MAGNESIAN LIMESTONE;

and though their geological situation is esteemed to be between the old red sandstone and the red marl, and in the foregoing order, yet, as they do not appear in the section, plate 5, fig. 2, further notice of them is deferred to page 212.

RED MARLE.

n. Plate 5, fig. 1 & 2.

This is a very extensive formation, stretching with little interruption from Torbay in Devonshire, to beyond the mouth of the Tees in Durham. It is in many places so closely associated with the old red sandstone, as that the transition from that rock through other sandstones,

* Geol. Trans. vol. 2, p. 29.

whose precise characters are not readily defined, into the red marle, causes an almost insuperable difficulty in defining its precise nature. It passes into sandstone in the range of hills which run north and south along the borders of Derbyshire and Staffordshire. This sandstone in some places is of a slaty texture. In the sandstone on the borders of Delamere forest, and elsewhere in Cheshire, are beds of marle enclosing rounded masses of granite, which are often of a large size; there are no granite rocks within 60 miles. The salt deposite, already described as having beds of clay and marle and gypsum above it, as well as the brine springs of Cheshire are situated in similar strata; and in Staffordshire, the coal dips towards it, but it is not ascertained that it passes beneath it. One of its characteristics, when not intermixed with other substances, is a softness which almost forbids its being ranked among rocks. Its prevailing colour, as its name imports is red; but it is usually more or less calcareous, and the most calcareous beds are of a bluish grey colour. In the neighbourhood of Bristol, coal, which lies above mountain limestone, passes away towards the east beneath the red marle; which also in various parts of the north of England overlies coal.

This formation does not appear to rise into hills of considerable elevation; they are on the contrary generally low, and with rounded outlines; many tracts of country occupied by the red marle are very flat. In the center of England, the Severn traverses it for a considerable length; and in the north, the Ouse and the Trent, streams tributary to the Humber, take a long course through its plains.

LIAS.

o. Plate 5, fig. 1 & 2.

The lias limestone is seen in the section reposing upon the red marle; between which and the oolite is its geological situation.

Lias is composed chiefly of carbonate of lime, but it involves some silex, and small quantities of oxide of iron, carbon, bitumen, and water; it is tougher than common limestone, and when of a bluish-black, it is termed blue lias; when of a greyish or yellowish white colour, white lias. These two varieties alternate with each other, and generally in thin beds. They enclose ammonites and a great variety of other sea shells, and are remarkable for enclosing the remains of crocodiles at Lyme in Dorsetshire. It is the argillo-ferruginous limestone of some authors; the calp of Kirwan.

By the map it will be seen that this rock extends from a little to the west of Ilchester in Somersetshire by Bath and Gloucester, nearly through the center of the kingdom, and terminates a little beyond Lincoln. A few miles north of Gloucester it rises to the height of 1134 feet above the sea.

Beds of a rock which has the same mineralogical, or rather chemical characters as the lias, are sometimes found in mountain limestone, but as these beds do not contain the same organic remains as the lias, they are not esteemed to belong to the same formation.

The lias burns into a very strong quick lime, valuable when made into mortar for its increasing hardness under water. It was therefore employed in constructing the Edystone lighthouse.

OOLITE.

p. Plate 5, fig. 1 & 2.

This formation is extremely extensive. Its geological situation is immediately upon the lias, and proceeds with it from Somersetshire, with but slight interruption, to the banks of the Humber in Lincolnshire. The Portland stone, the Bath stone, and the Ketton stone, are rocks which to a common observer would appear to be absolutely distinct. They are nevertheless considered to be of the same formation; when carefully examined, all more or less present the same roe-like texture, which is characteristic of the oolite of Bath; and they all enclose a vast number of shells of the same kinds. These circumstances, together with their being found in the same geological position in reference to the accompanying rocks, determine their identity. But in some places, beds of oölite occur in formations of earlier, as well as of later date.

A variety of the oolite is also called the roe-stone from the resemblance of the little round masses of which it consists, and which are particularly obvious in the stone of which Bath is built, to the roe of a fish. It is a very impure limestone, and will not burn into quick lime.

Some geologists have proposed to divide the numerous beds constituting the oolite formation, into an upper and under oolite; which has not received universal concurrence. It rises into hills of no considerable elevation above the sea. A few miles west of Banbury it is 836 feet, at Monckton Farley near Bath 700; and at Sherborne in Dorsetshire 635 feet.

FOREST MARBLE.

q. Plate 5, fig. 1 & 2.

This rock reposes immediately on the oolite. It occurs connected with one variety of it on the eastern side of the isle of Portland; and proceeds on the same side of the oolite from the southern part of Somersetshire to Sleaford in Lincolnshire. The forest marble consists of thin beds of compact limestone alternating with a slaty clay, and is characterized by the large quantity of organic remains enclosed in it; chiefly of small cornua ammonis.

CORNBRASH LIMESTONE.

r. Plate 5, fig. 1 & 2.

The name of this limestone is provincial in Wiltshire. It commences with the preceding rock in the southern parts of Somersetshire, and reposing upon it pursues an uninterrupted course, forming the high grounds in some parts of Oxfordshire and Buckinghamshire, to Olney; Bedford, and Peterborough in Northamptonshire, are both situated in it; and it occurs in spots higher north. It is a whitish, calcareous, and sandy rock, and is by some termed the Bedford limestone.

CLUNCH CLAY.

s. Plate 5, fig. 1 & 2.

In some districts of England indurated clay, when glossy, unctuous, and tending to a slaty texture, is called *Clunch*; when dull and smooth, it is termed *Clod*. The

term clunch clay is therefore provincial. This deposition consists of slaty clay of a bluish or blackish colour, which is often so calcareous as to form a coarse limestone. It is sometimes aluminous; often bituminous, forming a species of fuel which from its having been found at Kimmeridge in the Isle of Purbeck, has received the name of Kimmeridge coal. The clunch clay contains a great number of shells, cornua ammonis, small belemnites, together with beds of nodular iron stone. This deposition stretches almost without interruption from the southern part of Somersetshire nearly to Peterborough in Northamptonshire. It again appears a few miles north of that place to within a short distance of the southern bank of the Humber. For several miles of the latter part of its course the clunch clay rests upon the oolite, from which it is not separated by the Cornbrash limestone. Again it appears a few miles north of York, whence to the northern coast it rests upon the red marle; the strata which intervene in the middle and southern parts of the kingdom, viz. lias, oolite, forest marble, and cornbrash limestone, having altogether disappeared. At Whitby and several other places, the clunch clay is very slaty and so highly aluminous that extensive alum works have been established. Provincially it is termed alum shale. This formation does not attain any considerable height above the sea. Near the northern coast it rises to 784 feet, and has been penetrated to the depth of 300 feet below the level of the sea. It chiefly forms the lowlands of the vale of Bedford, and of the vale of the Isis, south of Oxford.

FERRUGINOUS, OR IRON SAND.

t. Pl. 5. fig. 1 and 2.

This also is an extensive deposition. It may be traced with considerable regularity from within a few miles south of Shaftesbury in Dorsetshire, nearly to St. Neots, in Huntingdonshire. It appears again on the eastern coast of Norfolk, and re-appears at Spilsby in Lincolnshire, for a short distance; and again in Yorkshire, accompanying the clunch clay to the northern coast of that county, covering the surface of a large district in the western parts of it. This stratum contains organic remains of various kinds, amongst which are cornua ammonis and the nautilus. In the vicinity of Woburn, in Bedfordshire, there rest upon the ferruginous sand considerable deposites of fuller's earth, which also appears under similar circumstances near Reigate in Surrey, as will hereafter be again noticed. In this sand near Woburn also is found the wood-stone, consisting of wood petrified by hornstone; occasionally also it contains beds of clay, shale, bituminous wood and limestone.

This sand, when it rises to the surface, in some places affords little else than heath; but in others, as surrounding Woburn, in Bedfordshire, it is now covered by extensive plantations of firs. The roads it affords are deep and loose. Leith hill, in Surry, which consists of this sand, rises to the height of 993 feet above the sea. At Brill, west of Aylesbury in Buckinghamshire, it is 744 feet high; but near its termination on the coast of Yorkshire, it attains the elevation of 1485 feet above the sea, at a place called Bottom head.

The next in order of formation is considered to be the

PURBECK STONE;

but not appearing in the section pl. 5. fig. 2, further notice of it is deferred to p. 217.

BLUE MARLE.

v. Pl. 5, fig. 1 & 2.

The Blue Marle succeeds the iron sand in the section, though the geological situation of the Purbeck stone is considered to be between them.

It accompanies the iron sand from a little to the south-west of Salisbury to the north-west coast of Norfolk, though not without interruption, which principally takes place in the low swamps of the Isle of Ely. It scarcely appears in the northern parts of England. It is the blue marle of Shotover hill in Oxfordshire in which are found the fine crystals of selenite; but in general it attains but little elevation; more often it is low, as may be observed in the vale of Aylesbury in Buckinghamshire, and in that of the White horse in Wiltshire. It forms a tenacious soil, remarkable for the growth of some of the finest oaks.

GREEN SAND.

w. Pl. 5. fig. 1. & 2.

This stratum has received the name of Green Sand from its containing little round masses of a green substance, having a considerable resemblance to chlorite,

which sometimes are so numerous as to give a green tinge to the aggregate of which they form a part; and which sometimes is considerably compact and hard, bearing rather the characters of a sandstone than of sand. It sometimes contains mica; the cement is calcareous. In this state it is abundant in the neighbourhood of Folkstone in Kent, in blocks of considerable dimensions, which were taken from the sand of the cliff in which they lie, and employed in the construction of the singular pier lately carried into the sea from that place; near which this formation may be traced stretching under the chalk. Though its geological situation is under the chalk, it is not precisely known to what extent it accompanies it; in the neighbourhood of Cambridge, for instance, the under chalk lies upon the blue marle; the green sand is in many places much intermingled with marle, forming an excellent arable land. This formation contains subordinate beds of limestone and chert.

CHALK.

x. Pl. 5. fig. 1 & 2.

The Chalk formation is very extensive. The extreme points at which it appears in the West of England are near Sidmouth and Honiton, in Devonshire. East of the latter place about 25 miles, an extensive range of chalk hills commences, extending in a north-easterly direction through Wiltshire and Bedfordshire, quite up to Cromer in Norfolk. It appears again in Lincolnshire, extending to Flamborough head in Yorkshire, interrupted only by the course of the Humber through it.

From the point above quoted in the West of England,

the chalk also extends south-east to the Isle of Purbeck, and appears again ranging through the center of the Isle of Wight. Near Hungerford in Berkshire, another range of hills commences, extending by Alton and Rochester to the coast between Folkstone and Dover, whence it proceeds to near Deal, appearing again in the Isle of Thanet. At Alton another range proceeds circuitously to Beachy head. Chalk hills are remarkable for a smooth rounded outline.

Near Royston the chalk attains an elevation above the sea of 481 feet; south of Dunstable it is 994 feet; south of Shaftesbury 941 feet; between Lewes in Sussex and Alton in Hampshire, various parts of the range rise to the height of between 800 and 900 feet, and the range between Alton and Dover, between 700 and 800 feet. The cliffs at Dover are 469 feet above the sea; those near Lyme in Dorsetshire are 580 feet.

It has been observed in treating of chalk as one of the great series of mountain rocks, that there are two distinct varieties of it (see p. 129); the upper, containing flints, and the lower, which is without them; some of their characteristic differences have also been pointed out. It may be said in addition that the upper chalk has its peculiar fossils, about 50 in number, which perfectly agree with those found in the chalk of France; they are in the general in a remarkable state of preservation. It sometimes contains a considerable quantity of siliceous sand that may be separated by washing it. The under chalk contains animal remains which wholly differ from those of the upper chalk. Ammonites are first found in it; and they differ from those of the strata which lie below it; the spiral coil approaches rather the oval than

the circle.* The differences existing between the upper and lower chalk have induced some geologists to consider them as distinct formations. The extent of the under chalk is not known; but it is supposed to accompany the upper. North of Newmarket, the upper chalk forms a range of high hills, and the under chalk, or grey chalk, crops or bassets out from beneath it on the north west, forming a parallel range of less elevation. It affords an excellent lime; and some of its beds, as well as those of the same formation near Reigate and Dorking in Surry, afford a sort of stone which is prized on account of its enduring heat, and is used for the backs of chimneys, and is thence called fire-stone. This stone is sometimes squared and used for the purposes of architecture. The cliffs of Dover consist of chalk containing regular layers of flint nodules, which, as they almost uniformly have a thick white covering of a substance which is chiefly siliceous matter, are considered to be in their original position. It is however clear that in some places this formation has undergone considerable ruin, as is evinced not only by the multitude of flints lying in the chalk vallies that have evidently been rounded by attrition, but similar flints occur in the chalk of Rottendean and the cliffs of Brighton, which consist of fragments of chalk intermingled with flints, clay, and sand; the whole having the appearance of being worn by the action of water.

Some account of the two Chalk basins of London and the Isle of Wight has been given, (p. 78). But it would appear by the annexed map that there are three basins formed by the chalk; the third being the district

* Geol. Trans. vol i.

comprehended within the irregular triangle formed by Dover, Beachy Head, and Alton. This district, though in appearance it forms a more regular basin than either that of London or the Isle of Wight, is only so in appearance. The various depositions within those points do not rest upon the chalk; they rise from beneath it, and therefore are older than the chalk. This is confirmed by the order of their deposition. The green sand, blue marle, and ferruginous sand (on the latter of which both in Surry and Bedfordshire, reposes the Fuller's earth) being precisely in the same order on the south of Rochester, as on the west of Salisbury. In both instances they rise from beneath the chalk. The district included between Dover, Beachy Head and Alton, is therefore beneath the chalk, and is of earlier formation.

A marle which is more or less argillaceous, and which at the same time partakes of the colour and somewhat of the appearance of chalk, is occasionally found immediately above, as well as beneath it; most commonly the latter. As this substance seems therefore to belong to the chalk formation, it has been termed *Chalk-marle*. It does not appear in the annexed map and section, and does not so constantly accompany chalk as to allow of its being considered as a regular stratum. It is found both above and beneath the chalk in the Isle of Wight. Chalk-marle is never quite so white as chalk, having usually a tinge of yellow, or of a grey or brown colour, and sometimes contains nodules of a more indurated marle called *grey chalk*. It contains no flints. It always falls to pieces by the action of frost, and finally pulverizes.

SAND.

y. Pl. 5. fig. 1 & 2.

In the annexed map and section the stratum which immediately reposes on the chalk is sand. It is of various thickness, character, and colour, and occurs in almost every direction in the neighbourhood of chalk. At New Charlton, a thin stratum of blue clay lies in it, containing oyster shells of different forms, some of them approaching to recent species; others are longer. A thin stratum of shells, imbedded in calcareous matter, succeeds; then 12 or 15 feet of alternating layers of shells, marle, and pebbles; beneath which lies a stratum of fawn-coloured sand 45 feet thick, which rests on chalk. At Bromley in Kent, oyster shells are found adhering to pebbles; the whole being formed by a calcareous cement into a coarse shelly limestone. Sand above the chalk is seen between Greenwich and Woolwich; it occurs largely both in Norfolk and Suffolk; the sand of Hampstead heath is considered to belong to it; and west of London it covers a very extensive tract of which Bagshot heath forms a part. In some places it contains beds of sandstone, of which the stones called the Grey Weathers in Wiltshire, and almost all the larger masses of the venerable Stone-henge, form a part. With this sandstone, a plastic clay occurs in some places, as at Cheam in Surrey, near Reading in Berkshire, and near Portsmouth. It is used in the manufacture of common sorts of pottery.

LONDON CLAY.

2. Pl. 5. fig. 1. & 2.

This clay has already been noticed (p. 80) in speaking of the chalk basin of London. It is commonly termed the Blue Clay from its general colour, but near the surface it is yellowish brown. It is characterized by the numerous septaria which lie in it in horizontal layers, and about 4 to 10 feet apart: they frequently enclose pieces of wood pierced by certain shells; and consist of an indurated argillaceous limestone, traversed by veins of calcareous spar, and sometimes enclose crystals of sulphate of barytes. This clay rises to a considerable elevation in some places, as in Shooter's hill, Highgate hill, and Langdon hill a little south of Billericay in Essex, which entirely consist of it, the first rising to the height of 446 feet, and the last to that of 620 feet above the level of the sea; and the hills which rise a little south of Waltham Abbey in Essex, and immediately contiguous to the London clay, if not chiefly consisting of it, attain the elevation of 750 feet. It forms steep cliffs in the Isle of Sheppey, and adding the height of these to the depth of the wells sunk in the neighbourhood, it is calculated that the blue clay is in that place 550 feet thick. This clay lies beneath and surrounds London for a considerable distance on the north, and still further on the east; extending beyond Billericay in Essex. In many places it rises nearly to the surface, being but slightly covered by vegetable mould; in others, considerable depositions of loam or brick earth and gravel occur upon it, and sometimes sand. These as well as the clay occasionally

contain the remains of sea animals; the brick earth sometimes abounds with sharks' teeth; but the teeth of a species of elephant have also been found in it. It has already been noticed that some faint traces of a deposite by fresh water resting immediately on the clay, are occasionally to be seen. The counties north-east of London, Norfolk and Suffolk, have not been examined with such nice regard to the geological nature of their strata as could be wished; a large portion, particularly of the former, is covered by sand. The appearances observed in many places around London, incline some geologists to the opinion that there are beds, if not distinct formations above the London clay; chalk rubble, or angular pieces of chalk, occurs in some places in beds of clay, as in the higher parts of Norfolk and Suffolk, resting upon it; but at Reading in Berkshire, brick earth rests immediately on chalk.

ALLUVIUM.

This consists of the loam, gravel, sand, &c. just noticed as resting in the neighbourhood of London upon the blue clay beneath it. It occurs in various parts of England resting on rocks of almost every variety.

Such are the strata over which it may be assumed that the traveller would pass between the Land's End in Cornwall on the west, and nearly the extreme point of Essex on the east. A section through this part (fig. 2. pl. 5.) has been chosen, not only because the geology of the southern counties is best understood, but also because this section exhibits a progress from the primitive to the alluvial strata without interruption. If we had chosen one from the Land's End to the

eastern parts of Kent, we should have exhibited the green sand, the blue marle, and iron sand, which occur in that order below the chalk west of Salisbury, as passing under the chalk near that place and rising again on the east of Alton, which is no doubt the case in point of fact. It may however be observed that, from what has been said respecting several of the strata, particularly of the numerous beds constituting the Oolites, and of the clays, marls, and sands, comprehended in the term red marle, as well as the several strata which overlie the chalk in the London basin, we have much yet to learn on the subject of the geology of England; and we may reasonably expect that much light will be thrown upon it by the great map which it is in the contemplation of the Geological Society to publish, and which it is expected will be accompanied by numerous sections, and by an ample memoir illustrative of the whole. From the combination of talent and ability, assiduously and unremittingly employed upon this great object, we hope to derive an intimate acquaintance with the geology of Britain.

It has already been observed that several rocks are found in England which either do not occur between Essex and the Land's End, or are situated so far beneath the surface, that they have not been seen. I proceed to some account of these; first again remarking that all the rocks which are found in England, or rather all such as it is important to our present object to notice, are arranged *in the order of their formation* in the upper corner of plate 5, on the left of the map; and that those rocks which do not occur in the section, fig. 2. of that plate, have a cross ✕ placed before the letters by which they are distinguished on the map.

GNEISS.

b. Plate 5.

This rock has already been mentioned as accompanying the granite of the Malvern hills. It also occurs, but is not common, in Cornwall, reposing on, or intermingled with the granite of that county.

The rock which, in the usually accepted order of formation succeeds gneiss, is so sparingly found that I have not thought it requisite to distinguish it in the series as one of the rocks of England. It is *mica slate* or *micaceous schistus*. Dr. Berger observed it lying beneath the serpentine at the southern extremity of the Lizard point. I am not aware of its having been noticed in any other part of England.

PRIMITIVE TRAP.

d. Plate 5.

This rock is exhibited in the map as occurring chiefly in the mountainous parts of Wales, in which only does it occur in any considerable mass, and will hereafter be further noticed in speaking of the geology of that country. In England it is described as accompanying the granite of the Malvern hills and of Mount Sorrel.

SERPENTINE.

e. Pl. 5.

This rock occurs chiefly as forming a considerable tract of country south of Helston in Cornwall, called

Gonelly Downs, and extending to the Lizard Point. The precise geological situation of this stratum has not been determined; in other words, geologists have not agreed decidedly in referring it either to the class of primitive or of Transition Rocks. If however it be an accurate description of primitive serpentine, that it is chiefly of an uniform green colour, the serpentine of Cornwall, which is of various shades of green and red intermixed, ought rather to be considered as a transition rock. It has been said that Dr. Berger noticed it reposing on mica-slate at the southern extremity of the Lizard; clay-slate is the rock which succeeds it on the north, (though their precise point of contact is not ascertained,) and which therefore interposes between the serpentine, and the range of granite hills. This rock does not I believe occur in any other part of England. It will hereafter be mentioned as occurring in huge blocks in the primitive and mountainous districts of Wales. Near the Lizard, serpentine encloses veins of soap-stone and asbestus; native copper, schiller spar, and diallage metalloide likewise occur in it.

SIENITE.

f. Plate 5.

Sienite and that variety of primitive trap which is termed greenstone, both consist of felspar and hornblende, and the chief difference between them seems to be this; the felspar of sienite is red or reddish, while that of greenstone is whitish or greenish. This rock is very sparingly found in England. It has been noticed only at Mount Sorrel in Liecestershire, and in the Malvern

hills, at both of which places it is associated with granite; in the latter of them it is so considerably decomposed, as almost to have lost its peculiar characters.

TRANSITION LIMESTONE.

g. Plate 5.

This rock is very sparingly found in England. It is generally agreed that the limestone of the neighbourhood of Plymouth, forming the left bank of the Plym, is of this kind, and that it alternates with graywacké in the north of Devonshire; by some also transition limestone is said to occur near Padstow on the northern coast of Cornwall, and somewhat to the north of the Malvern hills; but the character of these rocks is not sufficiently decided to remove all doubt. In Wales it is found in small quantity at some distance from Montgomery towards the north west. Near Plymouth it lies on clay-slate.

GRAYWACKE.

h. Plate 5.

Graywacké and graywacké-slate occur both in the northern and western parts of Devonshire, and in some places alternate, particularly in the neighbourhood of Hartland Point, forming strata, inclining in every direction, and in the most capricious and picturesque forms. These rocks are traversed by veins of quartz, are without organic remains, and are devoid of any appearance of having been formed from the ruin of earlier rocks.

They include no metallic veins; but wherever this rock alternates in the north of Devonshire, as has been already noticed, with clay-slate, organic remains are inclosed in it. *Dunstone*, in that county is the name of a rock which appears to be referable to the graywacké formation. It is there composed of fragments, supposed to be cemented together by the intervention of a paste resembling the matter of clay-slate, but very minute.*

This rock is bounded both in the south and north of Devonshire by clay-slate, and is believed to rest upon it, but the precise point at which the one begins and the other ends, is not accurately ascertained; the same may be said of its junction on the west of that county with the old red sandstone or red marle. This rock forms a considerable tract in Wales, and appears again north of Liverpool, stretching, near the coast up towards Kendal in Westmoreland. In neither of these districts does it appear that its limits have been clearly ascertained. In Wales there are several mountains in the graywacké district, about 1000 feet high. The Cradle mountains, situated in the same district, south-east of Brecon, are 2545 feet above the level of the sea.

MOUNTAIN LIMESTONE.

k. Plate 5.

This rock, which is common to Derbyshire and many other parts of England, has obtained the name of mountain limestone, to distinguish it from some other lime-stones, which though most of them agree in

* Geological Transactions, Vol. II. 496.

the character of forming considerable elevations, differ essentially from it in point of composition. It is one of the flœtz rocks of Werner, abounding with marine shells, and enclosing entrochi, coralloids, madrepores, &c. and at the same time it is intersected by numerous metallic veins, chiefly of lead, more rarely of copper. It sometimes contains beds of swinestone, as in Derbyshire, Shropshire, and Northumberland; and is associated with more compact varieties, which, as they admit of a high polish and are sometimes beautifully variegated, have obtained the name of marble.

The upper stratum of this rock in Derbyshire is of considerable thickness, sometimes amounting to 200 fathoms, and enclosing beds of marle. It rests upon another, the depth of which is not known, in which is seen the amygdaloid or *toadstone*, in England peculiar to Derbyshire. This rock is generally of a dark brown, sometimes with a greenish tinge, but differs greatly in appearance and hardness; sometimes it is porous and soft, sometimes nearly as compact as basalt; but at a considerable depth its cavities are filled with calcareous spar and sometimes with green globules. It has no appearance of stratification, contains no metallic veins, but on the contrary wherever it occurs, it cuts off those which traverse the limestone. The toadstone appears at the surface near Castleton and at some other places in the county.* *Greenstone* occurs in the toadstone, probably in a cave near Castleton.

A little north of Shepton Mallet in Somersetshire, the mountain limestone rises to the height of 999 feet above the sea; near its southern limit in Derbyshire, it attains 1154 feet.

* Mawe's Mineralogy of Derbyshire.

COAL.

l. Plate 5.

It is particularly worthy of remark, that in almost every part of England and Wales in which mountain limestone occurs, coal appears in the neighbourhood, and it is ascertained that in most instances the limestone rises from beneath it, as at Whitehaven in Cumberland and several other places in the north of England; at Swansea, it nearly surrounds the coal, which lies as it were in a limestone basin, and in other places in Wales, and near Bristol, &c. But in most instances, the coal does not repose immediately on the limestone; a bed or stratum of coarse gritstone or sandstone, containing rounded masses of quartz, intervenes. This is stated sometimes to contain mica, forming a sort of slate used in buildings; but is occasionally of a character which allows of its being used for mill-stones, and has therefore received the name of the *mill-stone-grit.* Its chief and most important use is for lining the furnaces of iron works, having the important property of enduring heat for many months, and to a greater degree than any other stone that has been discovered. This grit crops out near Castleton and other places in Derbyshire, forming a thick stratum at the surface.*

But in some places in Derbyshire a stratum of schistose clay lies upon the limestone, which has been seen to the depth of 120 yards; this stratum also crops out in many vallies; but there sometimes interposes between the clay and limestone a thin stratum of marle. The rottenstone is found on the surface of the limestone.*

* Mawe's Mineralogy of Derbyshire. † Ibid.

In the accompanying map (plate 5) it will of course be understood that for the most part the various colours are intended to represent the several strata as they are visible at the surface, or covered only by alluvial or vegetable soil. To this general rule, however, the large tract in the north of England, represented as being wholly occupied by coal, is an exception. Coal is not visible at the surface in that extensive district, except in certain places in which the strata basset out at the surface; it is covered, underneath the alluvial or vegetable soil by strata of several kinds, and in some places by the various rocks or substances included in the comprehensive term, red marle; and therefore, wherever coal is represented on the map, it will be understood only as exhibiting the fact, that such tracts are occupied by the *Coal-measures* or *Coal-fields*, as they are synonimously termed.

Some account has already been given of coal deposites, in which that of Derbyshire was not noticed. In this county, the superincumbent matter is generally a gritstone or sandstone. Thin beds of argillaceous ironstone, enclosing impressions of plants, coralloids, and shells, usually lie upon the coal; of which, in some places there are several beds with intervening strata of different substances, to which the miners have given the names of under-soil, gravel, bind, clunch, hardstone, metal, plate, &c. these beds are mostly clays or sandstones of various degrees of induration, and are sometimes only a few inches thick, and sometimes basset or crop out at the surface. At Newhall, near Derby, the strata above the coal are not numerous. Vegetable earth a few inches; to which succeed 12 feet of blueish argillaceous matter, then schistose clay in a state of decomposition 50 feet,

beneath which is a stratum of schistose hard coal; then follows indurated clay 10 or 12 feet, which reposes on a stratum of fine coal 8 or 10 feet thick.*

Along the borders of Derbyshire and Staffordshire, a range of sandstone hills take their course in the direction of north and south. A part of this range is slaty, and is considered to be the same rock as is described by Werner as belonging to the independent coal formation; beds of coal have been worked beneath it.

Coal is found in England at various elevations; in some places its outgoing is very low; in others it is greatly the reverse. In the Clee hills, about 12 miles north-west of Ludlow, in Shropshire, there are coal workings, 1805 feet above the sea; and at Water Craggs, about 15 miles west of Richmond, in Yorkshire, there are coal workings at 2186 feet above the same level.

MAGNESIAN LIMESTONE.

m. Plate 5.

This limestone, which differs from mountain limestone in having as one of its constituents, about 20 per cent. of magnesia, forms the great range of stratified hills extending from Nottingham to Sunderland. These hills do not rise high above the sea; a few miles north of Nottingham they attain 600 feet, and near Sunderland, on the north 632 feet above its level; the center of the range is less elevated. Its geological situation is commonly understood to be above the coal, but the truth of this is not yet placed beyond doubt. It is certain that the

* Mawe's Mineralogy of Derbyshire.

coal dips towards it, and in many places abuts against it. In one or two instances it has been seen to pass beneath the magnesian limestone; but mostly, when it comes in contact with that rock, instead of passing under it, the coal immediately dips down nearly at right angles with the horizon. It is nevertheless understood that the geological situation of the magnesian limestone is between the coal and the red marle already noticed. It occurs in beds in the mountain limestone of Mendip, in Somersetshire, and also in that of Derbyshire. It is found in Scotland and Ireland. It differs from common limestone in its external characters, in having generally a granular sandy structure, a glimmering lustre, and a yellow colour; and in the course of the range from Nottingham northwards, its surface in many places is covered by a poor herbage uncommon to limestone, attributable to the magnesia it contains, which is known to be unfavourable to vegetation.

PURBECK STONE.

n. Plate 5.

This stratum is described as consisting of a series of strata of shelly limestone, alternating with shale and marle. Some of the fossils of these strata strongly resemble fresh water shells; they appear to be the Cyclostoma, Planorbis, &c. The circumstances under which these strata appear, differ greatly. They are distinctly seen in the Isle of Purbeck, whence the stone takes its name; and it forms a considerable district in Yorkshire called the vale of Pickering. The same strata appear in Kent, rising, together with others from

beneath the chalk; from the coarseness of its texture it has been called the Kentish Rag.

But still other rocks exist in England which it would be impossible to exhibit with fidelity on so slight a map as accompanies this very brief outline view of the nature of its strata. One of these rocks is BASALT, which according to the divisions which the experience of Werner has induced him to make in rocks, belongs to the newest flœtz trap, the newest of the whole series of mountain rocks. This rock is very variable in appearance and is of doubtful origin. Its position, and the circumstances attending it, are such as sometimes to warrant the conclusion that it is of igneous origin; while other basalts are found under circumstances which warrant the conclusion of their being deposited from an aqueous solution. Without further notice of its origin, we shall merely state that basalt is found traversing some of the coal formations of England, in large veins, denominated by the miner *faults*, on account of the dislocation which they cause in the strata of coal. It occurs also on the banks of the Tees in Durham, both in the form of rocks and of columns, which sometimes are of considerable magnitude: also on the summit of Clee Hill in Shropshire, and in numerous columns on the north side of Cader Idris in Wales, some of which are situated with considerable uniformity of position, while others lie in every direction as if they had suffered by convulsion.

It has already been stated, that considerable difficulties yet attend the attempt of giving even a general outline of the geology of England, from the absence of those precise definitions which alone would render it valuable in the highest degree. Not only are the characters

of some of the formations composing its strata, but little understood, or if understood, so imperfectly made known, that the geologist is still far from satisfied respecting them; but also several of them hitherto have not received any accepted geological appellation: and therefore it has been requisite to describe them only by the names that have been given to them in some of the districts they traverse, and which therefore are to be considered rather as provincial than geological. It may be repeated that that there is much yet to learn respecting the geology of our country. The tracts which consist chiefly of primitive and transition rocks, are least understood, and the nature of many of the numerous limestone formations which traverse England in the direction of north-east and south-west, has not been precisely ascertained; but enough is known to assure us that *they are distinctly marked by the organic remains they enclose*, which often almost entirely constitute the rock, and retain their characters in a remarkable manner. In fine, a view of the Geology of England assures us of the truth of the assertion with which we set out—that *order in regard to deposition is universally prevalent*, *and that this order is never inverted.*

Keeping in view this important fact, we, who reside in a country which is of the newest formation, might amuse ourselves with speculations upon the distance which any one of the more ancient strata, which in the annexed map or section are seen cropping out in some of the western counties, dips beneath our feet. This can only be done as a matter of curiosity; for we cannot even hope to approach the truth, because of the uncertainty whether the numerous strata to the west of us do, or do not actually continue to dip towards the

east, for any considerable distance beneath the surface; even if we were to assume this to be the fact, for the sake of amusing ourselves with a calculation of some sort, we should still be at a loss as to the probable thickness of the several strata. Coal is one of the most important deposites, and therefore claims our consideration in as great, if not in a greater degree, than any other. On looking at the map we shall observe that the nearest place to London at which coal is found, is in the neighbourhood of Bristol, near which place it dips towards the east, beneath the red marle. In this country its geological situation is between it, and the mountain limestone. Coal is not seen in the section, Plate 5, fig. 2, but its geological situation being beneath the red marle, we may observe that there are very many formations or strata, supposing them all to dip together towards the east, intervening between the London clay and the coal. And when we recollect that the outgoing of the nearest coal is upwards of 100 miles from London; that the wells there pass upwards of 130 feet through the London clay before the sand which lies upon the chalk is arrived at, and from which the water springs; if again we consider that between the sand and the coal, the numerous strata extend *on the surface* over a tract of country about 40 miles in length from east to west, as from Hungerford to Bristol; and if moreover we imagine all these strata to be compressed *beneath the sand which covers the chalk*, into one twentieth part of what their outgoings occupy on the surface; we should even then be compelled to suppose that the strata of coal are more than two miles beneath the bottom of the London clay. How near the truth this calculation may be, or whether the coal and all the strata intervening between it

and the chalk pass away beneath our feet, we have no reasonable ground for concluding; but we are acquainted with the important geological facts, that the dip of the older rocks beneath the surface is much more highly inclined than that of the rocks of a middle age, and that the dip of the newer rocks becomes less and less inclined until we arrive at the newest, which lies nearly flat. This difference of inclination in rocks of different ages, it has been already mentioned, has caused Werner to designate the more recent of them by the name of flœtz or flat rocks, on account of their nearly flat position. We are moreover further acquainted with the fact that the dip of the formations on the east of the lias, all of which are newer than it, is very inconsiderable; so that the allowance we have made for the thickness of the strata between the bottom of the London clay and the surface of the coal may far exceed the truth, even though our allowance does not exceed one-twentieth of the distance which the outgoings of these strata occupy on the surface. The coal near Bristol dips towards the east, to use the miners' phrase, 3 feet in 6; in other words, if the stratum of coal be followed down from its outgoing at the surface for 6 feet, a perpendicular line let down to that point from the surface would be found to be 3 feet in length.

The characters of simple minerals, sometimes from mechanical admixture, sometimes from their chemical composition, afford much scope for conjecture respecting their actual nature. But the diversity of appearance and even of the composition of a rock is sometimes so great, that the same description would by no means suffice for the whole of it. In granites and in the rocks belong-

ing to the trap formation, this is peculiarly prevalent; especially in the latter, which occasionally assume the appearance almost of simple felspar in one part, and pass in a short distance, from a slight admixture of hornblende, into a rock having the character nearly of compact hornblende. The same circumstances attend rocks of almost every description in a greater or less degree; so that it becomes extremely difficult, if not impossible to judge of the nature of a rock, or a stratum, by the hand specimens deposited in the collection of the geologist; more especially is it difficult in many cases to judge of the precise nature of such specimens, so as to refer them at once to the formations to which they belong. To judge of this with accuracy, it is almost essential that the rocks from which they are taken should be seen *in situ;* and even in this most favorable situation, the experienced geologist is often at a loss to decide. These difficulties belong principally to the older rocks; those of a middle age, and more especially the newer are more readily recognized by the organic remains they contain.

The similarity in rocks of very different ages has often been the means of leading into error. It has been asserted that coal is to be discovered in the neighbourhood of Blackheath; this has doubtless originated in the similarity, which, to a common observer, there appears in the sand of that place to that overlying some of the coal formations in different parts of England. But the geologist, even though there might appear some similarity in the two sands, being aware that their geological situations are very remote, would without hesitation determine on the improbability of success: the sand of Blackheath is above the chalk, while that

which in some parts of England overlies the coal, belongs to the red marle formation, and is therefore far beneath it.

With regard to the general level of the country in England above the sea, it is difficult to form a precise notion; it may however be remarked that the Ashby de la Zouch canal which runs nearly due south from that place chiefly over the red marle, is 274 feet above the level of the sea at high water mark, and takes its course for 70 miles without a single lock.

It is also worthy of remark that the vallies which take their course *along the direction of the strata* at the surface, are longer, more open, and less rugged than *those which traverse the strata*, the smaller extent and more rugged surfaces of which denote, in the estimation of some geologists, that at least some of these are not attributable to the same cause as the former, namely, to that of regular deposition; but to a disruption of the continuity of the strata on the surface by various, remote, and inexplicable causes.

The space which is without colour, forming, according to the geographical divisions of England, the northern parts of Cambridgeshire and the eastern parts of Lincolnshire, and bounded on the north and east by *the Wash*, can scarcely be said to form a part of the geological features of England. With very little exception, it consists of fens and marshes: many thousand acres of it have been retrieved from the sea, which it is well known has at different periods retired from particular parts of our coasts, and again returned. Of this there is a remarkable instance on the coast of Kent. It is known that the sea once covered, and perhaps at no very distant period, the extensive tract of flat land

known by the name of Romney marsh, now affording pasturage for many thousands of cattle, whose security depends on the stability of a barrier of earth 14 miles long, called Dimchurch wall, which has been thrown up, and is kept in constant repair, to oppose the progress of the sea; the surface of which, at high water, is many feet above that of Romney Marsh. The eastern parts of Lincolnshire and the northern district of Cambridgeshire, (although a large part of them has of late been regained from the sea and is now cultivated,) were formerly, if not in a state of cultivation, yet considerably above its level, as is evinced by the nature of the numerous vegetable remains abounding therein. The trunks and roots of large trees are very frequently discovered: and it is not long since the trunk of an oak, 90 feet long, was found beneath the soil in the marshes on the coast of Lincolnshire.

§ 2. OF WALES.

Wales has not hitherto been sufficiently explored with a view to the comprehending of its geology, as to enable us to give a very decided account of it. The general character of the country, and particularly of its northern parts, is mountainous. In North Wales there are two mountain ranges, the central and most elevated parts of which are chiefly composed of primitive rocks, and whose direction, like that of most other ranges of the same description, is north-east and south-west. Of the more northern of these ranges, the summit of Snowdon forms the most elevated point, and that of Cader Idris of the other.

In neither of these chains, nor indeed in any part of Wales, excepting a small spot near the middle of the isle of Anglesey, does granite make its appearance.

The Snowdon chain is constituted of the whole mountainous tracts of Caernarvonshire. Snowdon consists of cliffs of different heights rising one above another. Its highest peaks are chiefly composed of porphyritic rocks of the trap formation, passing into nearly compact or schistose hornblende. Large blocks of serpentine of extraordinary beauty, occur on the mountain; and on its western side a large number of basaltic columns, some of which are evidently not in their natural position; the length of these columns varies considerably, but some of them are four feet in diameter. The sides of the Snowdon chain are covered by rocks generally partaking of the schistose character, and although their precise nature is not known, it is understood that the prevailing rock of North Wales is clay slate or argillaceous schistus. The outgoing of these rocks becomes lower and lower, as they recede more and more from the elevated trap formation forming the center. Upon the north of Snowdon on the banks of the Menai, separating Anglesey from North Wales, mountain limestone succeeds the clay slate. The latter rock may be said to be the prevailing rock of Anglesey; granite occurs near its center, and mountain limestone towards its southern side. On the north-eastern termination of the Snowdon chain, the graywacké formation makes its appearance, and is succeeded by mountain limestone.

The mountain chain of which Cader Idris forms the most elevated part, consists of many lofty peaks, and includes the mountains called the Arrans and Arennegs. The peaks and summits of this, as well as of the Snow-

don chain, are composed of rocks of the trap formation, which are succeeded on the north-west by those belonging to clay slate, and extending to Snowdon. The same rocks extend to the south-east of this chain, and are the prevailing rocks of the greater part of Wales south of it. On the north-west occurs graywacké; to which succeeds limestone, and afterwards coal; the same order prevails in the termination of the slate formation in South Wales; graywacké succeeds; then limestone, on which reposes the vast coal deposite, bordering the Bristol channel. In the great range of clay slate south of the Cader Idris chain, limestone occasionally makes its appearance, mostly bearing the characteristic marks of mountain limestone, but occasionally of a transition rock. Before we quit the subject of Cader Idris, it is important to mention that the porous appearance assumed by some rocks belonging to the trap formation, when in a state of decomposition, and which occur near the summit of Cader Idris, have induced some travellers to suppose that mountain, or at least some of its rocks, to be of volcanic origin. This opinion was the more plausible, and seemed to receive strong corroboration from the appearance of a large hollow, high up the mountain, now occupied by water, and forming a lake overlooked by steep cliffs, greatly resembling the crater of a volcano. It is however now decidedly believed that no trace of volcanic matter is to be found on the mountain.

The graywacké formation which is represented on the map as chiefly occupying the southern parts of Wales, but extending on the one hand to the northern coast, and on the other nearly to the western, at St. David's head, which is principally composed of primitive trap, is very

little known, either in respect of its character or extent. Its precise line of junction with the schistose rocks which occupy the surface of so large a portion of Wales has not been described; but it is certain that these rocks are found associated in various parts of that country. Graywacké is also seen on the north, near the western coast of Lancashire, extending into Westmoreland. The same rock occurs also in Devonshire.

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